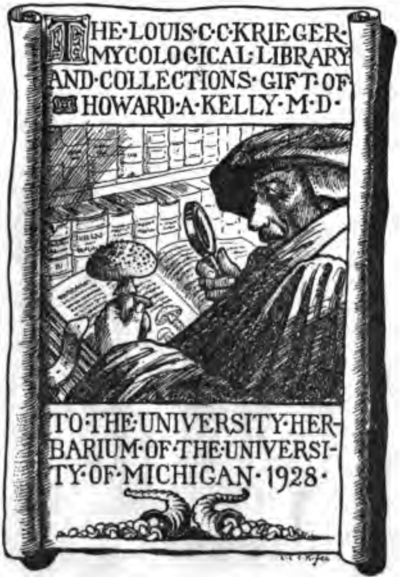
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DISEASES OF
FIELD AND GARDEN CROPS

FIG. 138.—DARWIN'S POTATO.
Solanum Maglia, Sch.

DISEASES

OF

FIELD AND GARDEN CROPS

Chiefly such as are caused by Fungi

BY

WORTHINGTON G. SMITH, F.L.S., M.A.I.
MEMBER OF THE SCIENTIFIC COMMITTEE
ROYAL HORTICULTURAL SOCIETY

WITH ONE HUNDRED AND FORTY-THREE ILLUSTRATIONS
DRAWN AND ENGRAVED BY THE AUTHOR

·SINE·FORMIDINE·
·SINE·FAVORE·

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TO

DR. BULL OF HEREFORD

AND

THE OFFICERS AND MEMBERS OF THE

WOOLHOPE CLUB

WITH THE GRATEFUL AND PLEASANT REMEMBRANCES

OF

THE AUTHOR

PREFACE.

The following notes on the Diseases of Field and Garden Crops are reports of a series of addresses given at the request of the officers of the Institute of Agriculture at the British Museum, South Kensington.

The addresses were preceded by a course of twenty lectures upon Vegetable Physiology in relation to Farm Crops, by Professor G. T. Bettany, M.A., B.Sc., F.L.S.; so that it was unnecessary, in speaking of plant diseases, to revert in detail to the structural and physiological branches, which had been covered by Professor Bettany.

The nature, limits, and objects of the addresses will be seen in the introductory remarks. In the lecture room actual examples of all the diseases in different stages of growth were exhibited, and the subjects were illustrated with *camera-lucida* drawings, as well as larger coloured drawings made from living examples. In the lecture room the simpler subjects were taken first, the students being gradually led on to the more involved ones. This arrangement has been adhered to in the present work, where the addresses have been put into book form, and numerous additions made.

The engravings are either reductions from the large drawings used at the lectures, or from others made from nature since. They are all (with the exception of one or two which it was necessary should be copies) original, and from living examples.

We hope the illustrations will be useful; we believe they are correct; they show what we have seen, or think we have seen.

Excellent preparations for the microscope of the fungi mentioned in these pages may be purchased, at moderate prices, from the Rev. J. E. Vize, M.A., Forden, Welshpool.

Our thanks are due for assistance to our friends Mr. Chas. B. Plowright, M.R.C.S., King's Lynn; and to Mr. A. Stephen Wilson of North Kinmundy, Summerhill, Aberdeen.

Most of the original *camera-lucida drawings*, with many of the actual examples, and a large series of microscopic preparations used at the lectures and for this work, are now in the department of Botany, British Museum (Natural History), South Kensington.

W. G. S.

LINDEN HOUSE,
DUNSTABLE,
BEDS.

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WHITE RUST DISEASE OF CABBAGES.

CLUB-ROOT OF TURNIPS, CABBAGES, MANGELS, AND ALLIED PLANTS.

EAR-COCKLE, PURPLES OR PEPPERCORN IN WHEAT, OATS, AND RYE.

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CORN MILDEW—SUMMER RUST AND MILDEW.

BARBERRY BLIGHT.

WILSON'S variety of *Claviceps* on Ergot.

DISEASES OF FIELD AND GARDEN CROPS.

CHAPTER I.

INTRODUCTORY.

IN preparing the following addresses we have endeavoured to keep three objects clearly in view. First, the description only of such diseases as are of economic importance. Second, the definition of all the phenomena of the diseases in familiar words, such as, with proper attention, may be understood by all; this has been done without sacrificing scientific accuracy, as all botanical terms in common use are adverted to and explained. Third, the consideration of the best means of preventing the attacks of plant diseases.

Many diseases of field and garden crops are too trivial in their effects to deserve notice: these will be either entirely passed over or but briefly referred to.

We do not propose to describe any diseases caused by members of the animal kingdom, with the exception of one or two caused by the attacks of Nematodes or microscopic worms. The diseases described are chiefly of vegetable origin, and mostly such as are caused by the parasitic fungi popularly termed mildews, moulds, smuts, blights, and rusts. The life history of some of these parasites is intricate: these will require close attention; others are more simple, and these simpler forms of disease

are taken first, so that the simpler examples gradually lead up to the more involved ones.

The great question of the prevention, palliation, or cure of plant diseases is, as a rule, almost entirely overlooked by botanists; but from a practical point of view,—and these notes are specially prepared for practical agriculturists,—the prevention, palliation, or cure of plant diseases should surely be an object to be kept chiefly in view.

A knowledge of the structure and vital phenomena of field and garden plants should be used as a sure stepping-stone to vegetable pathology. It must be confessed, however, that in the same way as surgery is often more precise and certain than medicine, so, much more is at present known of vegetable physiology and anatomy than the nature of disease and its prevention. We clearly know the nature of some diseases of plants; but as regards the treatment of plants when invaded by parasites which are too often the sole cause of disease, we frequently know nothing. The reason for this defective information is clear: there are no special teachers of vegetable pathology in this country, and the few men who have made the subject more or less a speciality, have not the time or opportunity for extensive and continued experiment and research. Field crops under disease are rarely or never examined by competent observers. As nearly every known disease of the animal kingdom is susceptible of preventive, palliative, or curative treatment, it is only reasonable to assume that the diseases peculiar to the vegetable kingdom are also susceptible of similar management. Of late years the spread of disease in the animal kingdom has been greatly curtailed, and in the human family the death-rate of towns has been much reduced. These results have been entirely brought about by the acquisition of an exact knowledge of the diseases peculiar to animals, and of the circumstances favourable to the spread or extinction of disease. Sanitary improvements have considerably extended the average length of human

life. It is therefore only reasonable to believe that when we completely understand the nature of plant diseases, and the circumstances which aid their spread or tend to their curtailment, we shall be more or less able to cope with them by rendering surrounding circumstances unfavourable for their extension. In the majority of instances it is almost futile to expect cures: the knowledge to be sought for must be the facts which will indicate some mode of prevention, or some method of detecting and treating disease in its earliest stages. In the same way as dwellers in towns have been of late aroused from their apathy and made to understand something of what is necessary for health, so all agriculturists should, if possible, arouse themselves and learn something of the nature and surroundings of plant diseases. Till this knowledge is acquired, and till agriculturists become alive to the possibility of saving their crops from disease, little progress can be hoped for. We do not say that it is necessary for every farmer to be a complete master of the anatomy and physiology of all the plants he grows, or to be perfectly familiar with the life history of every assailing parasitic fungus or destructive animal, any more than a householder should know all about the exact nature of typhus, or diphtheria, or bacteria, bacilli, and disease germs; but as every householder at length begins to know, amongst other facts, that an open drain is likely to prove fatal to life, so every farmer should know, amongst other things, that imperfectly-drained fields and rotting vegetable-refuse mean disease and destruction to his crops.

No sane healthy person would remain in a place tainted with the contagia of dead and diseased animals, and it is equally unsafe to place sound plants, tubers, or seeds, amongst dead or diseased vegetable-refuse. In one case, as in the other, certain individuals may perchance escape; but the general result is, the healthy organisms are at length destroyed by the dead or diseased ones.

In regard to the illustrations prepared for this work,

they are original, and have all been drawn direct from nature to uniform scales, and engraved by ourselves, so that the comparative degrees of largeness or smallness of the different parts of all the fungi described may be understood at a glance. Nothing is more wretched than the copying and recopying of book illustrations, too often bad ones, without examination or verification. To such an extent is this copyism at times extended, that in some instances, only one original drawing has ever been made, and every succeeding drawing, whether English, French, or German, is a mere slavish copy. The description, too, as well as the drawing, of one person is too often taken on trust alone for an indefinite period of time. The comprehension of some published illustrations is sometimes made difficult by the diverse and odd powers of magnification, such as × 17, × 131, × 316, etc., so that after the examination of a few illustrations a student's mind becomes greatly confused as to the relative sizes of the objects illustrated. All magnified figures should be in tens, hundreds, or thousands. Sometimes certain authors have illustrated fungi and omitted the amount of magnification upon the plates; they have simply inserted "slightly enlarged," "greatly enlarged," "still further enlarged," etc.; and the fact is certainly not creditable to the copyists when we say that every illustration copied from certain works with which we are acquainted reproduces these almost unmeaning terms. The fact shows that the whole phenomena described by certain writers have simply been taken by their successors on faith, and that no single copyist has taken the trouble to measure and verify for himself.

Students of nature should take very little on trust, for the sharpest observer is liable to make a mistake in what he thinks he sees, or in the meaning he attaches to what he sees, or fancies he sees. Therefore, as far as possible, every one should observe and think for himself, not with a view towards finding fault with other observers, but to

confirm, extend, modify, and check the observations of other men. Confirmations are not always to be trusted, for it often happens that a beginner is over anxious to confirm the statements of a master, as by that means the pupil hopes to secure some of the credit belonging to the original teacher. It is not only necessary to know what is confirmed, but who confirms it. Some older views of our own, in which we have now no belief, have been repeatedly "confirmed."

All phenomena which on the face of them are unusual should be carefully examined and re-examined, and constantly tested and retested. Reasonable statements may be more readily accepted than unreasonable, but it often happens that the more wonderful and unreasonable a phenomenon is—according to the descriptions—the more avidiously it is accepted, especially by beginners.

Opinions often vary as to the meaning of the phenomena connected with disease, as in the appearances presented by the fungi of corn mildew, of the potato murrain, and some other diseases. In these instances we shall not disrespectfully advance our own views to the disadvantage of other observers, but shall clearly and impartially state both sides of any disputed question. We shall, however, consider it our duty to say how our mind has been impressed by the evidence. Although certain facts are themselves often undisputed, yet the deductions made from them are hotly contested.

In concluding these brief introductory remarks, we strongly advise such of our readers as have the opportunity, to carefully examine the phenomena hereafter mentioned for themselves, and to accept nothing on mere faith. Any new observers who will sift and resift any statements of fact or deduction which appear to be unreasonable will be doing a real service to science.

CHAPTER II.

CLOVER SICKNESS—CLOVER MILDEW.

Peronospora trifoliorum, D.By.

The well-known weakly growth of clover, termed clover sickness, is said—perhaps on insufficient grounds—to be due to a deficiency of potash in the soil, especially the soluble salts of potassium in the subsoil. When clover is grown too frequently in the same fields, and without alternation of crops, the ground becomes "clover sick." Two nematoid or thread worms (nema, a thread) of minute size, and allied to the so-called "worms" of stale vinegar and paste, and to the Nematode which causes ear-cockle in wheat, oats, and rye, have been described as attacking clover. These thread worms have been described under the names of *Tylenchus devastatrix* and *T. Havensteinii*; but the impoverished condition of clover when due to these parasites is said to be distinguishable from clover-sickness proper. Some observers have said that the ailment is due to the presence of a fungus known as *Sphæria herbarum*, Pers., sometimes described as *Pleospora*, and more frequently as *Cladosporium*. This fungus is overburdened with synonyms and varietal names, and is so common on all herbaceous plants that it is hardly likely to be the sole cause of clover sickness. A second fungus, named *Peziza ciborioides*, Fr., it is also credited with being the cause of this ailment, but probably on insufficient evidence, although, from what we have recently learned of the attacks of the spawn or mycelium of a *Peziza* upon living potato plants, the presence of *P. ciborioides*, Fr., on clover deserves attention. A third fungus, named *Pha-*

cidium medicaginis, Desm., has also with insufficient reason been referred to as the cause of the disease. It is almost impossible to say what may be the chief cause of clover sickness, and there may be several forms of the disease. The spawn of fungi is sometimes confined to the interior of plants, where it causes serious disturbance, and this spawn or mycelium, if without fruit, even when seen under the microscope, is commonly so indefinite in character that no one can say for certain what fungus it is destined to produce.

A frequent fungus on dying clover leaves is *Ascobolus trifolii*, Riv., which is the same with *Phacidium trifolii*, Boud.; and another is *Polythrincium trifolii*, Kze., which is said by some authors to be a second condition of *Dothidea trifolii*, Fr. A rust fungus named *Uromyces appendiculata*, Lev., is also at times very prevalent on the pea-flower tribe. The fungus parasites of the *Leguminosæ*, to the pea-flower tribe of which our clovers belong, are but few in number, although their individual power for destruction is great. The best known are the mildews of our garden and field peas named *Erysiphe Martii*, Link., and *E. communis*, Schl., the latter of which also occurs upon the *Ranunculaceæ* and the vine. A close ally named *E. graminis*, D.C., is parasitic on grasses.

A very frequent parasite of clovers in Britain, and one to which we are inclined to refer a great deal of clover sickness, is *Peronospora trifoliorum*, D.By., a pest which appears to have attracted little or no attention in this country till late years.

It, like all other species of *Peronospora*, attacks living plants ; it is common on purple clover, *Trifolium medium*, L. ; *T. alpestre*, L.; crimson clover, *T. incarnatum*, L.; on Lucern, *Medicago sativa*, L., and other plants. There is some diversity of opinion as to the meaning of the name *Peronospora*, as Corda, the botanist who first used the name, gave no explanation of its derivation. Corda probably had in view the word *peronao* (περονάω—Homer and

Theocritus)—to pierce, pin, or transfix, or *peronē*, the pin or tongue of a buckle, a pointed or piercing object, and spora (σπορά), a seed or spore. He probably used the word in reference to the power of the fungus to pierce the tissues of the plant it attacks as distinguished from other fungi which have no such power. The specific name *trifoliorum* explains itself. *Peronospora trifoliorum*, D.By., is closely allied to the potato fungus, and it grows within and upon the under surface of the leaves of the plants invaded. By this habit of growth, and its putrefactive power, it not only chokes up the organs of transpiration of the host plant, but causes decomposition of the tissues by contact. It is remarkable for the profuse production of its minute, oval, transparent spores or *conidia*. A spore in fungi is a reproductive body, answering to the seed of flowering plants, but with no embryo or rudimentary plant within. Certain spores in *Peronospora* and in many other fungi are often called conidia from *konis*, dust, to distinguish them as secondary spores, or spores of an inferior class, the fungus itself being capable, under favourable circumstances, of producing other spores of a much higher order and more complex structure. The conidia in *Peronospora*, as the name indicates, are like fine, generally transparent dust. These conidia are filled with colourless protoplasm, or vital material, and they do not readily germinate except in water. When a conidium of *Peronospora trifoliorum*, D.By., falls upon any damp surface it bursts at the side, and the protoplasm exudes somewhat in the form of an amœba, one of the simplest animal organisms. From this irregular amœba-like form, other fertile stems of *Peronospora trifoliorum*, D.By., speedily arise.

The disease spots on the leaves, as caused by the *Peronospora*, are at first white, and speedily become pallid or brownish. At length the corroded fragments drop from the leaf to the ground. This species of *Peronospora* produces oospores, egg-like spores or resting-spores; these fall to the ground in the autumn, and rest in a hibernat-

ing state till the following summer, when they germinate, and produce threads carrying secondary spores or conidia; these conidia drop off from the parent plant, sail through the air, and are carried in different directions by currents of wind. Such spores as light upon clover plants cause the production of the mildew; such as fall on unsuitable places perish. A description of how resting-spores are produced, and their nature, is given farther on in this work.

The illustration of this fungus (Fig. 1, A) shows the parasite enlarged 400 diameters, growing from the under-surface of the foliage of *Medicago sativa* L., whilst one of the very pale gray spores or conidia is enlarged to 1000 diameters at B. In the illustration the fungus is really inverted so that its characters may be more easily understood. All species of *Peronospora* usually grow from the under surface of leaves, where they may be seen by the unaided eye as small white cottony masses. They commonly burst through the organs of transpiration—*stomata;* sometimes, however, the fungi push the leaf cells aside and so get access to the air from the interior of the leaf. Two stomata are seen in section at C, D. The fertile threads which carry the spores are termed by botanists *conidiophores* or conidia-bearers. The spawn of the fungus causes putrefaction of the tissues by mere contact. The spores, on falling on the foliage and bursting, also cause putrefaction of the leaf. The destruction of invaded clover is further aided by the conidiophores or stems of the fungi obliterating the organs of transpiration.

Imperfect drainage and thick planting favours the growth of all the *Peronosporeæ*, whereas a free circulation of dry air is often fatal to them. When once they make their attack, it must be remembered that they establish themselves within the tissues of the invaded plants, in a position where it is impossible to reach them with any curative material. Attention, therefore, to the mode of cultivation may tend to stop the spread, if not to prevent

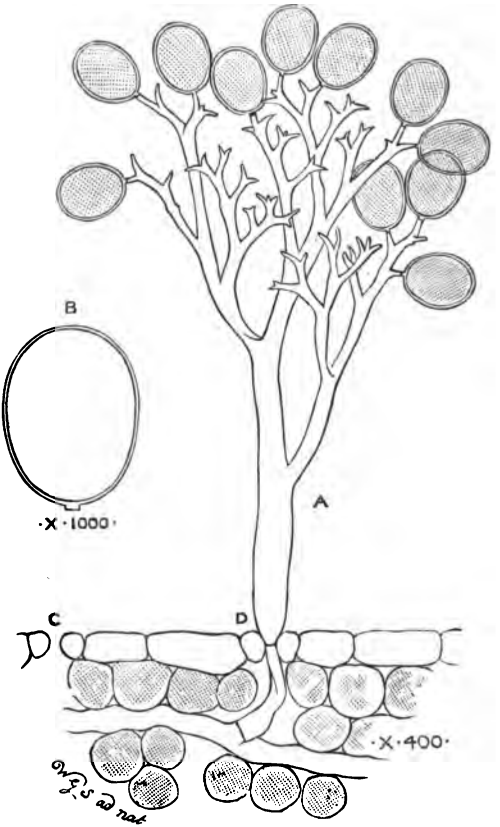

FIG. 1.—CLOVER MILDEW.
Peronospora trifoliorum, D.By.
Enlarged 400 diameters. Spore enlarged 1000 diameters.

the original attack of the foe. As the fungus hibernates in decaying clover plants in the winter, it is obvious that

the best mode of preventing attacks is, where possible, to destroy all clover refuse with fire, and not allow any to rot on the surface of the ground. This treatment will, of course, not only destroy the eggs of any nematoid worms, but the spawn of the other fungi so frequently seen on sickly clover plants in the summer and autumn.

The Nematodes appear to be attracted to the decayed spots caused by the *Peronospora*, for in these positions, in company with resting spores of the parasite, which undoubtedly causes one form of putrescence, we have commonly found them.

CHAPTER III.

PERONOSPORA EXIGUA, W.SM.

ANOTHER *Peronospora*, with the habit of *P. grisea*, Ung., a parasite of *Veronica*, is very frequent upon clovers in Britain, is equally destructive with *P. trifoliorum*,

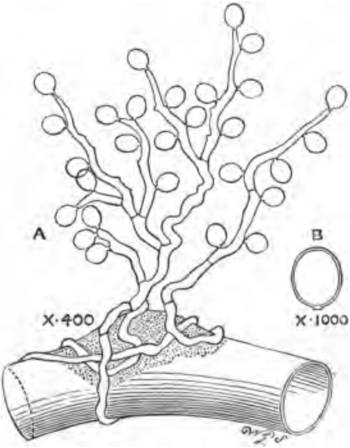

FIG. 2.—CLOVER MILDEW.
Peronospora exigua, W.Sm.
Enlarged 400 diameters. Spore enlarged 1000 diameters.

D.By., and is a minute and hitherto undescribed species. This plant, *Peronospora exigua*, W.Sm. (*exiguus*, small), is illustrated, enlarged 400 diameters at A, Fig. 2; and a

single spore, or conidium, is enlarged 1000 diameters at B. The parasite causes putrescence, and grows within the leaf and in effused patches on the surface, as does *P. trifoliorum*, D.By. The illustration shows a somewhat large group of fruiting fungus threads, growing upon a fragment of a leaf hair of *Lotus corniculatus*, L.; the mycelium has caused a gouty discoloured swelling to appear on the hair. The spore-supporting threads are frequently simple, or sometimes once, twice, or three times branched and furnished with a few joints, stops, or *septa;* the spores are borne on minute, often lateral spicules; and as the branches grow, the spores have a tendency to drop off, as in the *Peronospora* of the potato disease. The spores are slightly oval, almost round, and burst at the side on germination. *P. exigua*, W.Sm., sometimes grows on clovers in company with *P. trifoliorum*, D.By., but it is immediately distinguished by its very much smaller size, as well as by its specific characters. Though common, this species has hitherto been overlooked, probably because its appearance on clover leaves to the unaided eye is precisely the same with that of *P. trifoliorum*, D.By.

PERONOSPORA EXIGUA, W.Sm.—Minute, conidiophores simple or slightly branched, slender, sparingly septate, conidia oval, almost globose, very small, very pale gray, sometimes borne on one side of the conidiophore only, non-papillate, bursting at the side on germination. On *Leguminosæ*, often in company with *P. trifoliorum*, D.By.

The "New Clover Disease," described by P. Mouillefert in the *Journal d'Agriculture Pratique*, 1874, pp. 667, 670, and translated by Mr. William Carruthers, F.R.S., in the *Journal of the Royal Agricultural Society of England*, Vol. x., Part ii., 1874, is possibly one form of clover mildew, caused either by *Peronospora trifoliorum*, D.By., or *P. exigua*, W.Sm. In the disease described by P. Mouillefert the fungus appears to be chiefly confined to the base of the stems of clover. The author says he has

not been able to detect the fungus in the leaf, but, curiously enough, he gives an illustration of it in that position; he has not illustrated the spores, perhaps because they so readily fall from their little pedicels in *Peronospora*, and are easily overlooked. As this fungus doubtlessly hibernates in the same manner as the last, the only plan for lessening its ravages is to burn all decaying clover material.

This parasite is very near *Ovularia* (*Ramularia*) *sphæroidea*, Sacc.; but if the published descriptions are correct, our plant differs materially from the German examples.

CHAPTER IV.

NEW DISEASE OF POTATOES.

Peziza postuma, Berk. and Wils.

In the beginning of the month of August 1880, Mr. Ambrose Balfe, secretary to the Royal Horticultural Society of Ireland, reported to us a disease then invading certain crops of potatoes in the west of Ireland, in a manner hitherto unknown to him. The potatoes had been bought as "Champions," and planted in land which had been reclaimed from bog eight years previous to the outbreak of the disease. When the ground was reclaimed a coat of clay was spread over and incorporated with the soil. For the first three years potatoes were grown, followed by a year of oats, next the ground was sown with grass and meadowed, and lastly "champion" potatoes were planted. In preparing the ground for the potatoes sea-weed was first spread over the grass, and ten days afterwards it was covered with farmyard manure. The potato sets were laid on the manure, and then covered. Ridge planting was adopted. No doubt the mode of culture was defective, as it is bad in practice to place potato sets in immediate contact with decaying vegetable matter and farmyard manure; such materials always contain an immense number of disease germs both of animal and vegetable origin. The manure used for potatoes should always be old and thoroughly decayed, and it is perhaps best that the cut faces of the sets should be allowed to dry before they are planted. Some planters pass the cut surfaces rapidly across a hot iron with good effect, but others maintain that it is better to place the

freshly-cut sets in the soil immediately after cutting, and whilst the wound is still quite fresh. Planting in rank undecayed material is not only destructive to the material which is stored up within the tuber or set (material which is the food of the future plant), but it is also injurious to the young shoots and rootlets, for any hot, fermenting material acts as a poison to these growths, and diminishes the vigour of the infant plant. The conditions of planting in the instance here adverted to may, however, have had nothing to do with the disease which followed in the summer.

Until the attack now under description, the potato plants, as far as outward appearances went, were free from any taint of the fungus of the potato disease proper, named *Peronospora infestans*, Mont. The disease was first noticed in the beginning of July, at the time the potato flowers were opening; but there can be little doubt that it was in or upon the plants several weeks previously, as by its nature it would not attract much attention at first. It is strange that other potatoes named "Protestants," growing close to the "Champions," were not attacked. The appearance of the diseased plants was peculiar; they were covered within and without with a thick felt of white fungus spawn or mycelium. The growth of this spawn was so rapid and profuse that in a week or two the whole of the stems and leaves were reduced to tinder, the entire moisture belonging to the stems and leaves being exhausted by the fungus. Leaves are of such vital importance to plants that the destruction of them is synonymous with a cessation of the plant's growth. If the parts of a potato plant which are above ground get seriously injured or destroyed, there will be little or no further growth in the tubers. In the *Peziza* disease, now under description, the mycelium was not a putrefactive one as in *Peronospora*. It merely caused a sudden cessation of growth in the tubers.

Immersed in the thick felt of white fungus spawn,

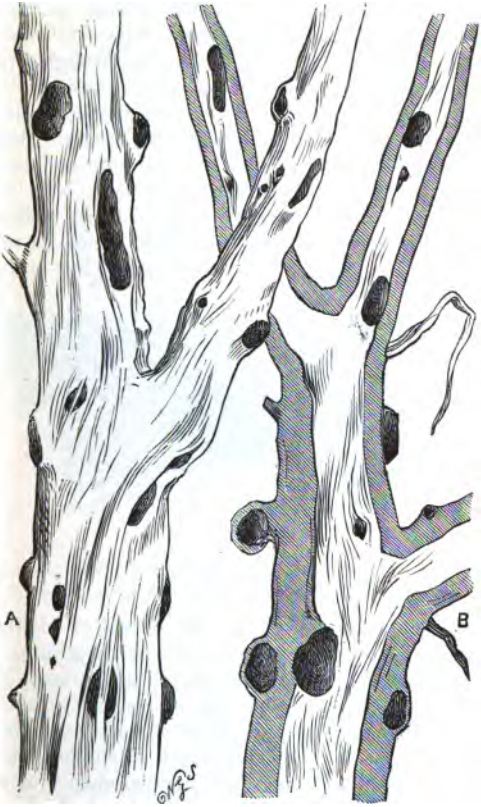

FIG. 3.—NEW DISEASE OF POTATOES.
Peziza postuma, B. and Wils. Potato stems with *Sclerotia*.
Natural size.

when it had reached its maximum of growth on the potato stems, there were thousands of small black nodular

bodies, varying in size from a grain of sand to that of a small bean. An affected potato stem is illustrated, natural size, at A, Fig. 3, and a section through a part of a similar stem is illustrated at B to show the black nodular growths *in situ*. The small black bodies here drawn are at first white, at length they become externally brown, and ultimately black; they are hard and compact, and, owing to their hardness, they have been termed *Sclerotia* from *sklēros*, hard. One of these bodies surrounded by spawn threads is shown, twice its natural size, at Fig. 4. These nodular growths when examined

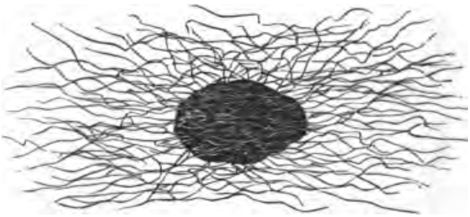

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FIG. 4.
**Sclerotium of *Peziza postuma*, B. and Wils.
Twice the natural size.**

with the microscope are found to consist of highly condensed and compacted spawn cells or mycelium, white in the centre and gradually getting black (through brown) towards the outside. When an excessively thin slice is taken off a cut surface of one of these nodules and magnified 400 diameters, the appearance is similar with the illustration at Fig. 5; here the gradual change of colour from the white internal cells to the black thick-walled outer ones is illustrated, together with the felted statum of white mycelial threads, on the top of illustration, in which the *Sclerotia* are embedded.

Sclerotia, or compacted masses of fungus spawn in a resting state, are common amongst fungi; some examples

never attain a larger size than a grain of gunpowder, others are as large as peas or small beans. The "Native Bread" or *Mylitta* of Australia, which often measures several inches across, may be a *Sclerotium.* The edible Americo-Indian *Tuckahoo*, which is dug out of the ground in large masses, is not really a fungus, although so esteemed

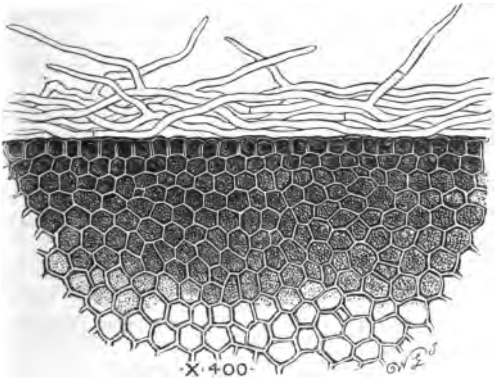

FIG. 5.
Section through outer surface of Sclerotium of *Peziza Postuma*, B. and W. Enlarged 400 diameters.

by Fries, and named by him *Pachyma cocos.* Some *Sclerotia* are sphærical in shape, whilst others are elongated irregular ovals. *Sclerotia* are not confined to one order or genus of fungi, but they possibly occur throughout the entire family. Some forms are much less compact than others, and the looser forms germinate after a comparatively short rest.

By means of *Sclerotia* certain fungi which would probably perish during drought or severe frost are preserved alive through inclement seasons. The spawn naturally compacts itself into these little hard masses and falls to the ground ; it there remains, like a seed, uninjured by continued cold or dryness, whereas the vitality of uncom-

pacted spawn would be destroyed under similar conditions in a few hours. *Sclerotia* vary in their period of hibernation from a few days to a year or more; they are somewhat erratic as to the required amount of rest; favourable circumstances will hasten on germination, whilst unfavourable ones will retard it; a very common period of hibernation is from nine months to a year. When germination at length takes place a perfect fungus is produced; this perfect fungus at maturity produces spores which, on germination, again produce spawn or mycelium. Sometimes this spawn will at once reproduce the perfect fungus, but in other instances it grows profusely, and at length gives direct rise to the little resting nodosities just described as *Sclerotia*.

Some *Sclerotia* on germinating only produce moulds or mildews, whereas others may produce a tall club-shaped fungus termed *Typhula*, from *Typha*, the reed-mace; some give rise to mushroom-like fungi, true *Agarics*, whilst others produce cup-shaped fungi which may be either sessile or supported on a long stalk; these latter fungi are termed *Pezizæ*.

Many *Sclerotia* have received specific names, but such names are almost valueless. For instance, two so-called different species of *Sclerotia* have been known to give rise to the same perfect fungus,—*Typhula phacorrhiza*, Fr. (*phacos*, a lentil, and *rhiza*, a root), grows either from *Sclerotium complanatum*, Tode, or *S. scutellatum*, A. and S. Both *Sclerotia* are found on dead leaves, and although they have been described as distinct they must be the same with each other. *Polyactis cinerea*, B., and *Peziza Fuckeliana*, D.By., both spring either from *Sclerotium durum*, P., or *S. echinatum*. For this reason some botanists esteem the *Polyactis* to be an early state of the *Peziza*. Whilst respecting the opinions of the botanists who have advocated this startling view, we are inclined to suspend judgment and wait for confirmation. *Polyactis cinerea*, B., not only grows on *Sclerotia*, but is extremely

common on all decaying vegetable matter when no *Sclerotia* are present. No one can tell for certain, by mere examination, what any given *Sclerotium* will produce on germination. Sometimes a clue is given to what a *Sclerotium* may possibly produce by observing its *habitat.* For instance there is one *Sclerotium* named *S. fungorum*, P., commonly found in dead examples of certain members of the mushroom tribe, chiefly found under the genera named *Agaricus* and *Russula*, and sometimes inside the large decaying corky fungi, named *Polyporus*, of trees ; these *Sclerotia* invariably produce a small mushroom-like fungus named *Agaricus tuberosus*, Bull. A closely allied *Agaric*, named *A. cirrhatus*, Sch., also springs from a not dissimilar *Sclerotium.* Another and very small *Sclerotium* found in decaying onions and named *S. cepævorum*, B., produces a minute mould named *Mucor subtilissimus*, B. It commonly happens, however, that *Sclerotia* may be found on the surface of the ground near where the supporting plant has decayed. When gathered from such positions it is impossible to say what they will produce under culture, and sometimes they so closely resemble small truffles (which, too, are often found on the surface of the ground), that without a microscopical examination it is impossible to distinguish one from the other. The perfect state of some *Sclerotia* is unknown, as *S. stipitatum*, Fr., found in the nests of white ants in India.

When the large black *Sclerotia* were found in Irish potatoes they appeared to us to differ from the *Sclerotia* we had hitherto noticed, and although it is never safe to guess at what an unfamiliar *Sclerotium* may produce, yet in our printed report, published in the *Gardeners' Chronicle* for 20th August 1880, we hesitated to refer the bodies to any already described form of *Sclerotium. Sclerotia* are by no means uncommon in herbaceous stems, in cabbage stumps, and even in potato stalks ; but the new bodies did not appear to us to be the same with any others we had previously observed. Black *Sclerotia* are not uncommon

in dead potato stems in the spring, but not on living potato plants in the summer.

Great efforts were made both by ourselves and numerous friends to make the new potato *Sclerotia* germinate, but in every instance that year without result. Many enquiries were made of potato growers, but the *Sclerotia* appeared to be lost again to this country, and nothing more was heard of them till a paragraph appeared in *Nature* for 19th July 1883. This described, from *Natureen*, a so-called hitherto unknown form of the potato disease, which had been making slow but steady progress near Stavanger during the previous ten or twelve years, and was then, so said the report, showing increased energy. The potato stalks were reported to be the first parts affected, and here Herr Anda had discovered small white fungoid growths, which, after attaining the size of a small bean, finally assumed a black colour. It appears that the fungus at Stavanger, like the same growth on the west of Ireland, rapidly increased at the expense of the supporting plant, first reducing the interior of the potato stem to a pulpy condition, and then shrivelling and hollowing it out until nothing was left but the mere outer shell. About the end of July or the beginning of August the destruction caused by the fungus is seen at its worst, and at this period whole fields of potato plants are often reduced to the condition of withered straw.

Now this disease at Stavanger, which was more or less lost sight of in Britain for three years, was clearly identical with the one reported on by us; it agreed in every way, and we at once wrote a note to *Nature* expressing our regret that although the germinating *Sclerotia* had apparently been seen by Herr Anda, yet the perfect plant had not been identified; so that, so far as Herr Anda's report went, we were as much in the dark as before as to the fungus which had caused the disease. A few days after our letter was published, our friend Mr. A. Stephen Wilson, of North Kinmundy, Summerhill, by Aberdeen

—who, it may be said, had not seen our note in *Nature*—sent us a box enclosing numerous living examples of the desired black *Sclerotia* from potatoes grown near Aberdeen. Mr. Wilson informed us in an accompanying letter that he had hundreds of similar examples from the previous year's potato stalks then germinating, and that, judging from the appearance they presented at that time, they would probably produce a *Peziza* allied to *Peziza tuberosa*, Bull. At the same time a third letter appeared in *Nature*, this time from Professor Blytt, stating that he had forwarded examples of the *Sclerotia* to Professor De Bary, and that they had germinated with him. Professor Blytt stated that the *Sclerotium* had produced a fungus identified by Professor De Bary as *Peziza sclerotiorum*, Lib., a species which had not at that time been recorded as British. At the period when this discussion was going on we received other living examples of *Sclerotia* from Mr. Thomas Carroll of the Gilbert Institution, Glasnevin, Dublin. Mr. Carroll stated that the disease was prevalent on the west coast of Ireland, especially on land too heavily manured. On making further enquiries we learned that the disease was spread generally over the counties of Sligo, Mayo, and Galloway, and that it was by no means confined to any special variety of potato; that the manuring with seaweed had nothing to do with the disease, but that large patches of potato plants twelve to fifteen yards in diameter were destroyed by the spawn of the *Sclerotium*, and the most luxuriant crops were apparently the most affected. The apparent luxuriance of the affected crops was perhaps not real, for it is well known that when some plants are first attacked by fungoid diseases they put on a spurious appearance of luxuriance, and are excited into a sudden quick growth. It has often been remarked that the apparently most healthy potato plants fall first before the disease caused by *Peronospora infestans*, Mont. The reason is found in the fact of the spawn of the *Peronospora* being capable of exciting a sudden

abnormal growth of chlorophyll or leaf-green, and in other ways causing a morbid enlargement of the tissues, termed hypertrophy. A transitory and spurious appearance of unusual health and vigour is not peculiar to the attacks of fungi, for insect injuries often excite the same appearances. It is well known that the largest and best-looking pears in orchards in the early summer are often swarming with larvæ. The larvæ stimulate the growth of the young pears; probably this abnormal growth is an effort of nature to repair an injury. The larger fruits fall to the ground and decay about the end of May.

Mr. A. Stephen Wilson succeeded in raising such a large crop of *Pezizæ* from his *Sclerotia* that he supplied us, as well as the Rev. M. J. Berkeley, and several other botanists, with living examples. They came up in large numbers in a garden bed where the *Sclerotia* had been thrown the previous year. The *Pezizæ* were all attached to the *Sclerotia*, and Mr. Wilson even detected the *Pezizæ* growing from potato stems with the *Sclerotia in situ*. Mr. Wilson considered the *Sclerotium* to be *S. varium*, P., a well-known pest of carrots, parsnips, cabbages, Jerusalem artichokes, etc. Mr. Berkeley came to the conclusion that the *Peziza* was a new species, to which he gave the name *P. postuma*, Berk. and Wils. in the *Gardeners' Chronicle* for 15th Sept. 1883. Whatever the name of the *Peziza* should be, there is one thing quite certain, and that is, the plant is new to the scientific observers of this country. The genus *Peziza* derives its name from *Pezica*, a word used by Pliny to denote a fungus; and Messrs. Berkeley and Wilson termed the plant now under description *postuma*, because the perfect plant is produced at a much later period than the *Sclerotium*.

There are at least thirteen or fourteen of these long-stemmed *Pezizæ* described, and the present plant comes so near *Peziza ciborioides*, Fr., *P. sclerotiacea*, Ces., and *P. sclerotiorum*, Lib., that it is almost impossible to distin-

guish it from them. The rest of the described species have smaller sporidia.

A few of the germinated examples forwarded by Mr. Wilson are illustrated, natural size, at Fig. 6. It will be

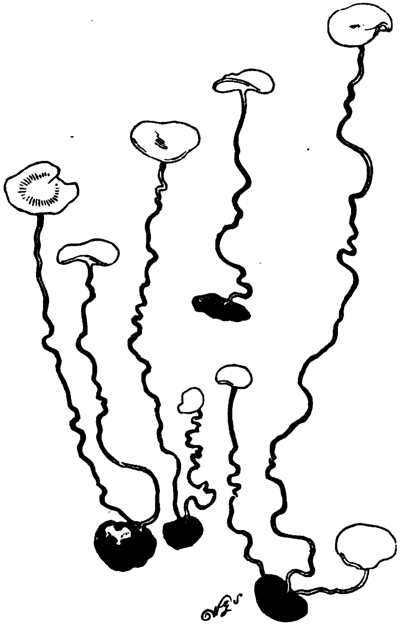

FIG. 6.
Peziza postuma, B. and W.
Natural size.

seen that the *Sclerotia* give rise to long, slender, tortuous stems, and that each stem at length bears a shallow pallid head, which ultimately becomes flat or slightly recurved. The stems are about two inches high, and the cup-like

expansion at the top about half-an-inch across. On closely observing these expanded tops in sunlight, especially when held in favourable positions, as against a black background, a slight sudden cloud resembling a puff of smoke or steam may be seen to gradually sail away through the air from the top surface. This almost invisible cloud really consists of millions of minute spores, in this instance technically termed *sporidia* for a reason to be mentioned immediately.

The whole interest of the fungus now centres on the expanded top, and especially to its surface, whence the clouds of *sporidia* sail away. If we cut one of the cups in two, and look on the cut surface with a magnifying power of five, and twenty diameters, we shall see the structure as shown at A and B, Fig. 7. We now notice

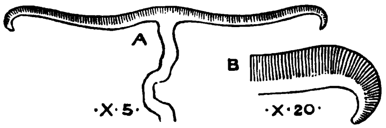

FIG. 7.
Peziza postuma, B. and W. Section through cup.
Enlarged 5 and 20 diameters.

that the whole of the upper stratum of the expanded top consists of elongated perpendicular cells as illustrated, whilst the under surface is a mass of spherical cells of various sizes; but to see this curious structure well a much higher magnifying power is required, and a small fragment only of the top must be examined in section, as at Fig. 8, magnified 400 diameters. We now distinctly see the basal stratum of transparent globular cells of various sizes, and a few of the hundreds of thousands of vertical transparent bladders forming the top stratum, and from which the cloud of dust consisting of oval transparent *sporidia* arises. With a lancet we will now remove a few of these vertical *asci* or long bladders, and magnify

500 diameters. Each colourless bladder, sack, or bottle, is termed an *ascus*, from *askos*, a bag, bladder, or bottle. Each *ascus*, as at Fig. 9, contains eight oval spores or *sporidia*. These bodies, one of which is farther enlarged

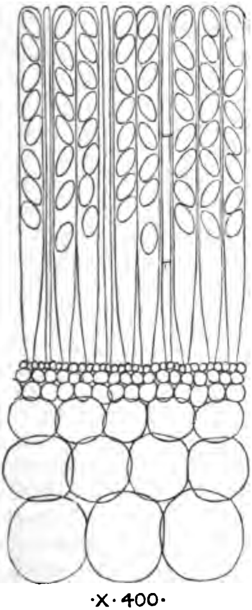

FIG. 8.
Peziza postuma, B. and W.
Section through fragment of cup.
Enlarged 400 diameters.

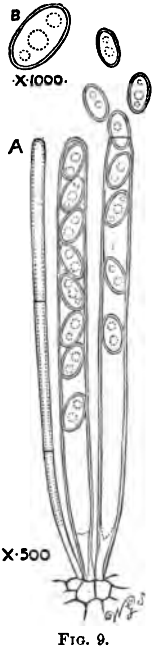

FIG. 9.
Peziza postuma, B. and W.
Asci, paraphysis, and sporidia.
Enlarged 500 diameters.

to 1000 diameters at B, are termed *sporidia* because they are not supported on threads or fine branches like many other spores, but are carried free in an *ascus* or transparent bladder, in which position they have arisen from a dif-

ferentiation of the protoplasmic contents of the *ascus*. Mixed with the *asci* are numerous slender, often septate organisms, termed *paraphyses* (as at A, Fig. 9), or organs which grow about or in company with organs of greater importance. The word is derived from *para*, about, and *phuō*, I grow. The right hand *ascus* in the illustration is shown in the act of discharging its *sporidia* into the air. At a given moment, depending upon unknown conditions, possibly of the air, of light or heat, the *ascus* opens at the top, as illustrated (in some fungi an *operculum* or lid flies off), and discharges the eight *sporidia* which it invariably contains into the air. In the genus of fungi named *Ascobolus*, the *ascus* itself, with its contained spores, as the name indicates, is shot into the air. Each transparent *sporidium* is furnished with two or three lustrous spots. The *asci* are so inconceivably small, slender, and attenuated that there are more than 300,000 packed side by side on the top of each expanded cap, which on the average measures about half-an-inch in diameter; and as each *ascus* contains eight *sporidia* there are no less than 2,500,000 *sporidia* produced by every cap. Now, as every infected potato plant will produce at least fifty *Sclerotia*, it follows that a plant killed by this new disease is capable, by means of its germinating *Sclerotia* during the following season, of discharging more than 100,000,000 reproductive bodies into the air. It must now be specially noted that after a year's rest the *Sclerotia* germinate on the ground, and there produce their *sporidia* exactly at the time in July when potatoes are making their best growth. A vast number of the *sporidia* must perish, but such as fall upon potato plants (and possibly some other plants, as carrots) germinate at once, cover the stems with spawn, obliterate the organs of transpiration, and speedily reduce the haulm either to a mass of putrescence or to dry tinder. During this rapid and exhaustive growth the spawn again gradually compacts itself into the black nodules of condensed mycelium termed *Sclerotia*, and

these nodules are destined to germinate and produce the *Peziza* disease the following year.

The remedy for this state of disease is obvious. No infected stems should be allowed to rot in the fields, but all should be carefully gathered together and burnt. If the stems are allowed to rot on the ground the disease is almost certain to recur ; but if they are burnt not only will the *Sclerotia* of the *Peziza* be destroyed, but the spawn, germs, eggs, and spores belonging to numerous other parasites, perhaps equally bad with the *Peziza* itself, will be destroyed at the same time. If, on an examination of the potato stems, it is found that many of the *Sclerotia* have dropped from them, the top surface of the ground should if possible be raked and burnt. Nothing is more common than to find hibernating reproductive bodies falling readily to the ground. This is clearly a natural provision for their preservation.

CHAPTER V.

FUSISPORIUM DISEASE OF POTATOES.

Fusisporium Solani, Mart.

WHEN potatoes are destroyed by parasitic fungi in the autumn, it does not always happen that the parasite is the dreaded putrefactive fungus of the murrain, named *Peronospora infestans*, Mont. Another highly destructive fungus, named *Fusisporium Solani*, Mart., is sometimes equally damaging to potatoes with the *Peronospora* itself. The name *Fusisporium* refers to the spindle-shaped crescent form of the spores,—*fusus*, a spindle; *Solani*, of course, refers to the genus *Solanum*, to which the potato belongs.

It often happens that *Fusisporium* grows in company with *Peronospora* on potatoes, at other times the two fungi grow apart; exactly the same phenomenon of consortism occurs with *Peronospora Schleideniana*, Ung., and *Fusisporium atro-virens*, B., on onions. The same consortism also occurs with *Peronospora parasitica*, Pers., and *Fusisporium aurantiacum*, Lk., on the cabbage tribe.

Fusisporium Solani, Mart., although very common in the southern and midland counties of England, has not been recorded from Wales or Scotland. Two allied species attacking the parsnip and turnip have been noticed in the latter places; and it appears strange that the *Fusisporium* of the potato should have been overlooked if it really occurs. But however rare the fungus may be in the north and north-west, it is certainly an extremely common and highly destructive pest of potatoes over the greater part of England.

Like many other fungi, *Fusisporium Solani*, Mart.,

occurs in more than one form. One condition of the pest, named *Periola tomentosa*, Fr., was described in 1836 as an assailant of potatoes in the midland counties by the Rev. M. J. Berkeley. This form is probably no other than masses of compacted villous mycelium or spawn, from which the *Fusisporium* at length arises. Another and early condition of *Fusisporium Solani*, Mart., was also described by Mr. Berkeley under the name of *Dactylium tenuissimum*. A distinct rose-coloured species of *Fusisporium*, named *F. roseòlum*, Steph., also grows on decayed potatoes.

Fusisporium Solani, Mart., is not peculiar to decaying potatoes, for it grows with rapidity on potatoes which are apparently undiseased, if bruised or cut. To the unaided eye its growth bears such a close general resemblance to *Peronospora* that it might readily be mistaken for it; indeed, the use of a lens, even with practised observers, is often necessary to distinguish between the two. The fungus is simple in structure, and consists of threads and compound spores; the spore-bearing threads springing direct from a floccose, sometimes mucilaginous, bed of spawn or mycelium, as illustrated at A, Fig. 10, enlarged 400 diameters. The fruiting threads carry spores attached somewhat obliquely, as illustrated at B, but more clearly seen in Fig. 11, where they are enlarged to 1000 diameters. The spores are spindle-shaped—that is, attenuated at both ends; and curved like a crescent: each spore, at first simple, is at length furnished with about three joints or septa, and each of the four pieces of the compound spore exhibits one or more lustrous spots. Sometimes all four parts of a spore germinate whilst still attached to the supporting threads, as at C, Figs. 10 and 11; but it often happens that at maturity the spores fall into four pieces, as at D, Fig. 11, and each of the fallen pieces sometimes germinates at once. This rapid germination, by its extension of the parasite, accelerates the destruction of the host plant. The fallen pieces of the spore are at

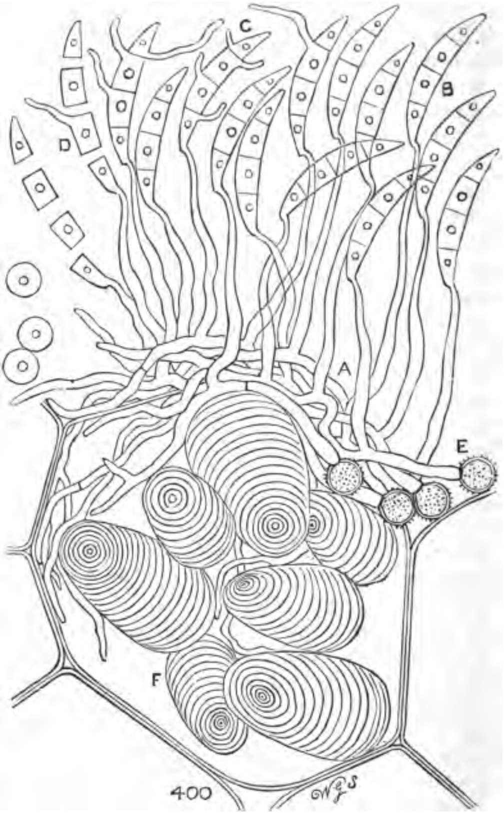

FIG. 10.—DISEASE OF POTATOES.
Fusisporium Solani, Mart. Enlarged 400 diameters.

first squarish, but on alighting on any moist surface they speedily take a spherical form. Sometimes these little bodies do not germinate at once, but hibernate for a short

time, generally varying from three weeks to three months (two months is a common time), and during this period they become slightly spinulose, and faintly tinted with a brownish hue. These little bodies, therefore, hibernate after the manner of resting-spores, and it is possible that many of them rest during the entire winter. A spore which has hibernated is shown at E, Fig. 11. The ovate

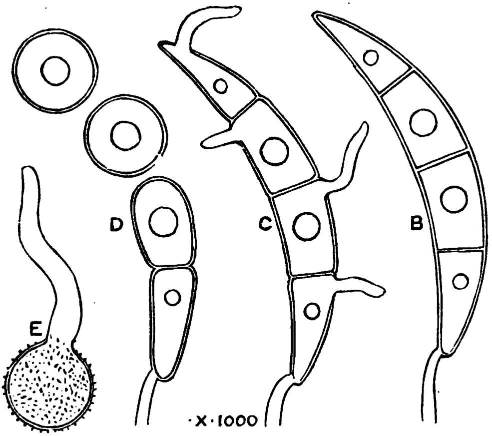

FIG. 11.
Fusisporium Solani, Mart. Spores in different stages of growth. Enlarged 1000 diameters.

bodies at F, Fig. 10, are grains of starch within a cell of the potato tuber.

The destruction of potatoes is complete when the *Fusisporium* works in company with the *Peronospora*, and when the spawn-threads of both fungi are interlaced, a condition very often observed in the midland and southern counties.

In experimenting on the growth of this fungus, it is very easy to transfer the flocculent or semi-mucilaginous

spawn from a diseased potato to a thin slice cut from an apparently sound one. If a very thin transparent slice of a sound potato is placed on a glass slide, and some of the spores and threads of the *Fusisporium* placed near the edge of the apparently healthy living slice, as illustrated in Fig. 10, the rapid progress of growth in the fungus can be observed with ease if the material under experiment is kept moist. The growth of the *Fusisporium* is extremely rapid, and the production of the compound spores most profuse. The small hibernating spores burst and produce a perfect *Fusisporium* in six hours. The mycelium appears to have the property of breaking up the cell walls, of injuring the contained starch, and of speedily reducing the potato to a loathsome mass of putridity. In certain instances the presence of the *Fusisporium* appears to cause the substance of the invaded potato to rot and become dry. The fungi found under *Fusisporium* are not generally considered to be capable of producing putrescence of tissues, but *F. Solani*, Mart., is an exceptional species; the mycelial threads and the supporting threads of the spores differ from typical species of the genus. A profuse growth of *Fusisporium Solani*, Mart., when seen under the microscope, looks like the surface of a field of corn, the ears being represented by the closely-packed *Fusisporium* spores. For lessening the attacks of this fungus, the only known plan is to destroy all affected material with fire, and not allow any decayed potato-refuse to remain in the fields.

CHAPTER VI.

SMUT OF POTATOES.

Tubercinia scabies, B.

THE smut which produces one form of scab in potatoes is caused by an olive-green or brownish fungus, of subterranean habit, named *Tubercinia scabies*, B.; from *tuber*, an ancient Roman name for a fungus; *cineres*, ashes; and *scabies*, the itch. This is the same with *Rhizosporium Solani*, Rab., and is the *Protomyces* of Martius. The smut fungus, which is very common upon potatoes, is supposed to be allied to the bunt of wheat, *Tilletia caries*, Tul.; and the smut of corn, *Ustilago carbo*, Tul. It was described and illustrated by Martius, *Die Kartoffel-Epidemie*, p. 23, tab. 2, Figs. 9-13, tab. 3, Figs. 36-38, and afterwards by the Rev. M. J. Berkeley in the *Journal of the Royal Horticultural Society*, vol. i., 1846, page 33, Figs. 30 and 31. The spores are compound, and are composed of minute cells, which together form a hollow globe with one or more apertures. In this character *Tubercinia* agrees well with the allied genus *Urocystis* (formerly *Polycystis*, in reference to the spores being composed of many cells), to which the well-known smuts of rye and violets belong. The fungus grows beneath the bark of the tuber, where it forms a thin dark greenish-brown stratum, often extending over the greater part of the external surface of the potato. The presence of the fungus may be detected by discoloured blotches on the bark. As in the disease caused by the *Peronospora*, it often happens that no trace of the fungus is to be seen at the time of harvesting. It frequently shows itself during the winter in stored potatoes, which,

at the time of digging, were apparently quite sound. In bad cases small discoloured spots first appear on the bark of the tuber; these increase in size and become confluent, till at length the entire skin of the potato is discoloured. The cuticle then bursts in many places, and the olive-green spores are liberated. Like many other plant diseases, potato smut is in some seasons rare, at other times it is very common and destructive. No potatoes showing traces of smut should be planted as seed.

CHAPTER VII.

SCAB AND CRACKING OF POTATOES.

THE brownish scab on the skin or bark, and the cracking of the bark in potatoes, are probably due to one and the same cause, and that a mechanical one. Scab and cracking are often confounded with smut in potatoes, but whereas the latter ailment is invariably caused by a fungus, there is seldom any fungus present (unless it be one of the species which so commonly follow injuries) in scab and cracking. Cracked and scabbed potatoes are not marketable, and as the fissures in the bark expose the inner substance of the potato to the earth it is generally said that tubers so injured possess an earthy and disagreeable taste foreign to uncracked and unscabbed examples.

Scabbing and cracking begin at a very early stage of growth in the tuber, and both are at first seen as small corroded spots, or minute open pustules; in bad cases the spots and cracks become confluent, and the whole bark of the potato presents an unsightly appearance. When the inner substance of the potato is once exposed minute insects, and sometimes fungi, add to the injury. If such fungi as *Peronospora* or *Fusisporium* light on the exposed places, destruction of the tuber is soon complete.

Scab and cracking are said, in the first instance, to be due to the presence of some irritating or corrosive substance in the soil. Continued drought, and possibly sudden and superabundant moisture, will also cause one form of scab. A natural effort is made by the potato to repair the injury, and so a hard scab originates; when

insects and fungi light on the injured parts, repeated efforts are made to repair the damage, and so the bark is brought into a scabbed and cracked condition. Lime rubbish, builders' refuse, refuse from ashpits, and other materials of the same class, are said to cause corrosion, scab, and cracking of the bark of potato tubers by contact. When the bark is carefully removed small depressions are clearly seen, answering to the scabs removed with the bark. In bad cases the pits beneath the scabs are excavated deeply into the substance of the potato, and when the bark is removed the substance of the tuber, though frequently slightly discoloured, is left intact.

It generally happens that a portion only of a crop of potatoes is scabbed, and this portion can be often distinctly traced to one part of the field whence the potatoes were derived. On visiting this position the irritating substances in the soil will usually be seen. When scab and cracking can be thus traced the remedy is obvious.

CHAPTER VIII.

NEW DISEASE OF ONIONS.

Puccinia mixta, Fl.

THERE are few kitchen-garden crops more liable to disease than onions, and in the best managed fields and kitchen gardens, and in dry as well as wet seasons, whole crops of onions, and all varieties alike, are liable to be swept off by the attacks of fungi.

During the summer of 1883 great attention was directed to a fungus named *Puccinia mixta*, Fl., found growing on chives, near Shrewsbury. The name of the genus *Puccinia* was given in honour of Puccini, a Florentine professor. When we remember how completely *Puccinia malvacearum*, Mont., has, during the last few years, destroyed all our best garden hollyhocks, we may well feel some anxiety as to the course this new pest of onions may pursue. Mr. William Phillips, F.L.S., of Shrewsbury, was the first to detect the onion parasite, named *Puccinia mixta*, Fl., growing in a garden. Mr. Phillips recorded its occurrence in the *Gardeners' Chronicle* for 14th July 1883, and there stated that the parasite was growing on chives, *Allium Schœnoprasum*, L., and the crop, he said, was in a deplorable condition of disease, the leaves and scapes, or naked flower-stems, being covered with yellow and brown spots, and presenting a miserable appearance. Mr. Phillips was good enough to forward some specimens to us at the time of finding, and from these examples the illustrations have been made.

Chives are perennial and indigenous to Britain. They are grown to no great extent in England, but in Scotland

they appear in nearly every kitchen-garden, where they are grown for flavouring soups, and as ingredients for salads. They are much milder than "scallions," *i.e.*, thickly-sown onions, which have no room allowed for the formation of bulbs.

At Fig. 12 is engraved a fragment of a scape or flower-stem of an affected plant of chives, enlarged five diameters, to illustrate the enormous number of disease pustules with which the flower stem, together with every other part of a diseased plant, is covered. It is curious that the scapes are first and most affected. When these pustules or ulcers are examined with a strong lens they look like little masses of brownish dust distinctly growing beneath the epidermis of the host plant. As the disease runs its course, and these pustules enlarge in size, they burst open the epidermis, and the brown or blackish matter, in the form of fine dust, is set free in the air. The pustules or masses of brown dust-like spores, for such they are, are technically called *sori* from the Greek, *soros*, a heap.

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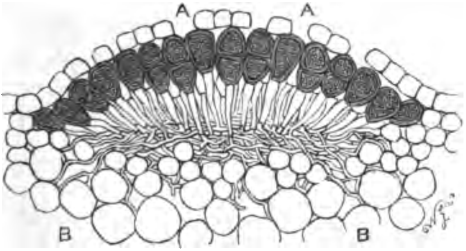
FIG. 12

NEW DISEASE OF ONIONS. *Puccinia mixta*, Fl. Fragment of flower scape of chives. Enlarged 5 diameters.

To understand the nature of the brown dust contained in the *sori*, a very small *sorus* must be selected and removed from the leaf; then, with a keen lancet, it must be cut either transversely or longitudinally in two, and the exposed surface examined. The illustration at Fig. 13 represents a transverse section through one of the smallest *sori*, viz. a disease speck, only one-hundredth of an inch across, magnified 200 diameters. The transparent epidermis of the scape is seen broken at AA, and some of the constituent

cells of the scape are illustrated at BB; between these positions the fungus named *Puccinia mixta*, Fl., is seen. The parasite consists of club-shaped bodies, each consisting of a brown head supported on a transparent peduncle or stem, the whole growing from a matted base of brownish fungus spawn or mycelium within the substance of the invaded plant. It will be noticed that the brownish bodies supported on the slender stems are of two classes,—one perfectly simple, consisting of a single cell; the other of two conjoined cells, or of a larger cell with a distinct transverse joint or *septum* across the middle. These



·X·200·

FIG. 13.
Puccinia mixta, Fl. Section through a *sorus*.
Enlarged 200 diameters.

bodies are spores of a peculiar class, possessing the functions of resting-spores, and called technically teleutospores; the latter term meaning "finishing spores," or the last spores produced; from *teleutao*, finishing. From the occurrence of the two sorts of spores in each *sorus* the fungus under description has been specifically distinguished under the name of *mixta*. The two varieties of teleutospore are farther enlarged to 1000 diameters at Fig. 14 to show more clearly the cell-walls. Under the microscope the colour of the spores is rich transparent yellowish-brown; the supporting threads are almost colourless. In some

species of *Puccinia* these teleutospores germinate without rest; but in the majority of instances they hibernate or rest in a quiescent state for eight, nine, or ten months;

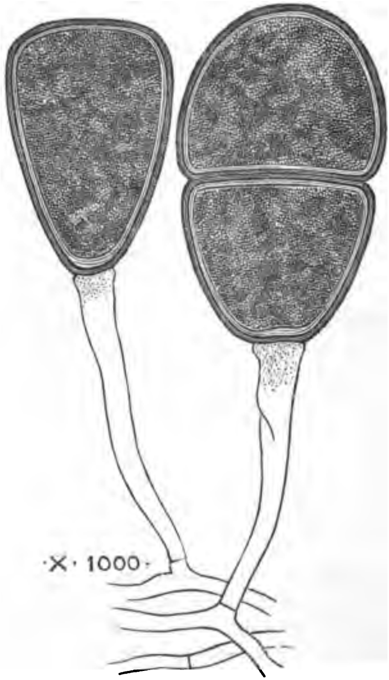


FIG. 14.
Puccinia mixta, Fl. Teleutospores or resting-spores.
Enlarged 1000 diameters.

they then germinate in the peculiar way described further on under *Puccinia graminis*, Pers., one of the fungi of corn mildew. The teleutospores of *P. mixta*,

Fl., have not yet been seen to germinate in this country, and the different experiments made in that direction by Mr. Phillips all failed, as he at the time foresaw they would do. The teleutospores of *Puccinia mixta*, Fl., as found in this country in July 1882, will probably not germinate before the forthcoming spring or summer; we shall then know whether the species is here capable of being artificially spread on to other members of the genus *Allium*. It is supposed that the fungus, long known as British under the name of Garlic Rust,—*Uromyces alliorum*, D.C., and sometimes as *Uredo alliorum*, D.C., or *Uredo porri*, Sow., is possibly one form of the plant now before us. It grew with the *Puccinia* on the same plants of chives at Shrewsbury. On the Continent there is a *Puccinia* named *P. allii*, Rud., found on Wild Garlic,—*Allium ursinum*, L.; and another bearing the same name is found on *A. oleraceum*, L., which is the same as *A. virescens*, D.C. It is probable that neither of these two fungi (each named *Puccinia allii*) are the same with each other or with our *P. mixta*, Fl.

On the Continent *Puccinia mixta*, Fl., is said to grow in three distinct forms on the same host plants. These forms have been termed the *Æcidium*, the *Uredo*, and the *Puccinia* forms; *Æcidium* and *Uredo* are fully described under *Puccinia graminis*, Pers., one of the fungi of corn mildew. At present the *Æcidium*, supposed to belong to *P. mixta*, Fl., has not been found in Britain. Elsewhere in Europe *P. mixta*, Fl., grows on various species of *Allium*, inclusive of chives,—*A. schœnoprasum*, L. It has been recorded on *A. acutangulum*, Schrad.; on the Garlic, *A. sativum*, L.; the Rocambole, *A. ophioscorodon*, Don.; the Wild Rocambole, *A. scorodoprasum*, L.; the Leek, *A. Porrum*, L.; *A. rotundum*, L.; the Onion, *A. Cepa*, L.; the Welsh Onion, *A. fistulosum*, L.; *A. carinatum*, L.; *A. palustre*, Pourr.; *A. flavum*, L.; *A. stellatum*, Gawl., and no doubt others. As we have all these plants in our gardens, it is of course possible, and perhaps probable, that they may soon act as

host plants here for *Puccinia mixta*, Fl., as they do on the Continent, and that we may be unfortunate enough to speedily see our onions, leeks, and garlic in the condition of the Shrewsbury chives.

There is an *Æcidium*,—the earliest stage, according to many observers, of a *Puccinia*,—found abundantly on our wild garlic, *Allium ursinum*, L., and named *Æcidium Allii*, Grev.; which is said to give rise, not to a *Puccinia* on *Allium*, as might have been expected, but to a *Puccinia* on *Phalaris* or *Digraphis arundinacea*, Trin., one of our common river-side grasses. It seems strange that although we have the *Æcidium* in the greatest abundance, and the grass upon which its ultimate or *Puccinia* condition should grow, yet *Puccinia sessilis*, Schum.,—for such is the name of its other supposed form,—has not yet been recorded as British.

The only method at present known for preventing attacks of *Puccinia* is to burn all affected plants and all field and kitchen-garden refuse on which the *Puccinia* has grown. In decaying refuse the spores hibernate, and they should be killed during the period of hibernation.

CHAPTER IX.

MILDEW OF ONIONS.

Peronospora Schleideniana, Ung.

ONE of the best known fungus pests of Onions is the dreaded onion mildew caused by the fungus named *Peronospora Schleideniana*, Ung. As its name indicates, it is a close ally of the fungi of clover mildew, *Peronospora trifoliorum*, D.By., and *P. exigua*, W.Sm., already described, and of the fungus of the potato disease, *Peronospora infestans*, Mont.

Peronospora Schleideniana, Ung., is named in honour of the botanist Schleiden. The fungus is illustrated, enlarged 200 diameters, at Fig. 15 ; it is shown as growing from the base of a leaf near the collar of the bulb; at this position there is but little leaf-green or chlorophyll in the cells of the leaves. The spawn or mycelium of the fungus ramifies amongst the loose cells of the leaf and sets up decomposition in its progress. At Fig. 15, A, the threads of the fungus may be seen emerging through an organ of transpiration into the air. The minute openings, "mouths," organs of transpiration or *stomata*, occur abundantly on most plants,—generally on the under surface of the leaves, but also in various other positions. The general habit of the different members of the genus *Peronospora* is to grow within the leaves and stems, and send their fruiting branches through the stomata into the air. This habit is fatal to the growth of the host plant, for the spawn not only causes putrefaction of the inner cells of the leaf and stem by contact, but the fertile threads choke up the organs of transpiration and prevent

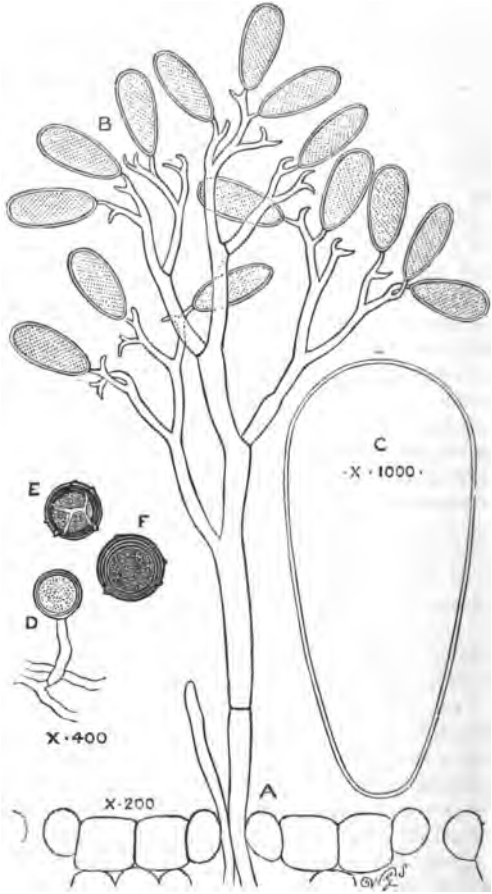


FIG. 15.—MILDEW OF ONIONS.
Peronospora Schleideniana, Ung. Enlarged 200 diameters; resting-spores, 400 diameters; single spore, 1000 diameters.

the evaporation of water in the form of vapour from the plant attacked. So potent are the different members of the genus for evil that their spawn threads are capable of pushing aside the plant-cells of the plants attacked either from without or within. The mycelium of some species has also the power of piercing through the cell-walls and traversing the interior of a plant, not by creeping between the cells, but by breaking down the cell-walls in its progress. Putrefaction attends the whole progress of growth of the invading *Peronospora*. The complete tree-like habit of the fungus of onion mildew is shown in Fig. 15. It will be noticed that the fungus repeatedly branches and rebranches, and at the ends of all the minor branchlets the ovate spores or acrospores termed *conidia* are borne. These are shown at B, and a single conidium is farther enlarged to 1000 diameters at C. The conidia are pale gray or pale lavender in colour, and are very large in comparison with the conidia belonging to other species of the genus *Peronospora*. At the time of germination the spores usually burst at the side. At Fig. 16 part of the *Peronospora* is enlarged to 400 diameters, so that the different illustrations of the genus in this work may be presented uniform in size. The difference in size between *Peronospora Schleideniana*, Ung., Fig. 16, and *P. exigua*, W.Sm., Fig. 2, is very great. From the irregular mass of protoplasm exuded at the time of germination mycelial threads and fruiting branches quickly arise. The fungi of clover mildew are transparent and almost colourless in all their parts, whereas the onion fungus is more or less tinted with a pale reddish-gray, a brownish, or a dull violet hue throughout. This is especially noticeable in the comparatively large conidia. The Rev. J. E. Vize, of Forden, Welshpool, has found the resting-spores of this species in decaying patches upon onions, where the *Peronospora* in its conidium-bearing state previously existed. The *oogonium*, or unimpregnated *oospore*, or resting-spore, is shown at D (Fig. 15),

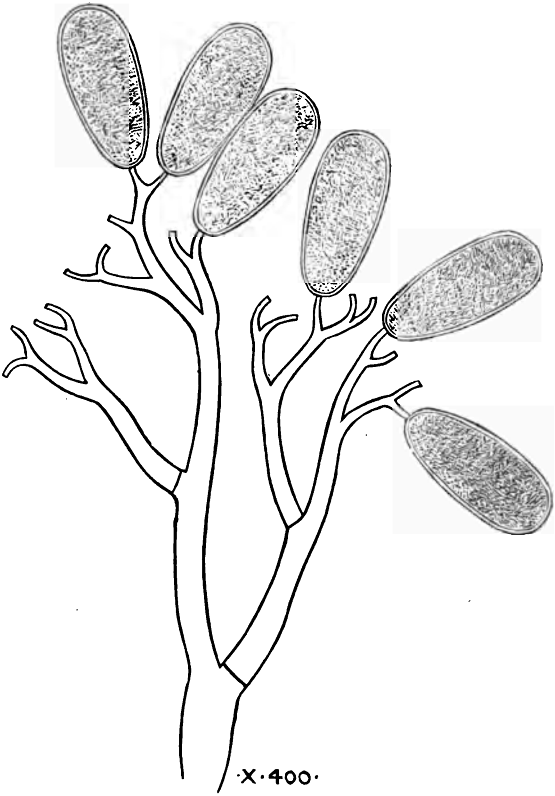


FIG. 16.—MILDEW OF ONIONS.
Peronospora Schleideniana, Ung. Enlarged 400 diameters.

and mature fertilised oospores or resting-spores at E and F, enlarged 400 diameters. These bodies carry on the life of the fungus in a hibernating state during the winter

months. Their mode of formation is described under *Peronospora infestans*, Mont.

Peronospora Schleideniana, Ung., is specially common on the garden onion, *Allium Cepa*, L., and on the Rock, Welsh onion, or stone leek, named *Allium fistulosum*, L. The latter plant does not form a true bulb, but is sown to form small green onions for spring salads. The fungus attacks numerous other species of *Allium*, and is even suspected on lilies and amaryllids. It is sometimes extremely common and virulent, attacking the onions early in the season, and so preventing the bulbs from reaching perfection. The chief point of attack is the leaves in an early stage of growth, and to such an extent is the work of destruction sometimes carried on that the entire onion plant may be seen covered with one mass of whitish-gray semi-transparent bloom. In bad cases the onions are left as one offensive mass of putrescence.

One form of mildew is caused by the attack of a *Fusisporium* named *F. atrovirens*, Berk. This fungus is not unlike *F. Solani*, Mart., already described, but the spores are grayish-green or greenish-black in colour and more decidedly curved. The disease begins with the exhibition of grayish gelatinous spots, which speedily become confluent. The *Fusisporium* often accompanies the *Peronospora*. Both mildews materially affect the crop of seed. Practical growers say mildews are favoured by an extremely dry season, as in the mildew of peas and roses, and also by a wet and cold season, as well as by bad cultivation. Deep trenching is generally advocated for the prevention of onion mildew.

A good plan for the avoidance of mildew in onions is to sow the seeds in autumn ; by following this plan the onions are able to make good strong growths before the appearance of the mildew in the following spring. This is perhaps the only reliable plan for obtaining sound onions of a large size in districts subject to attacks of mildew. Autumn sowing is advocated by onion growers.

This is said to prevent the attacks of the onion-fly, for it is believed that the flies select the younger onions for the deposition of their eggs in preference to those of more mature growth.

Where possible all mildewed material should be burnt, for no fact is better known than that mycelium or fungus spawn is often perennial.

Like many other plant ailments, the diseases of onions require investigation. Several forms of disease are known to growers, of which no explanation has at present been forthcoming. In one form the whole crop turns sickly yellow just before ripening, the tops soften, the bulb becomes detached, the roots decay, and the entire growth soon becomes rotten. Another disease causes the onion to become thick and soft-necked, the bulb in proportion being small. Sometimes mildew attacks the full-sized and apparently not thoroughly-ripened bulb after it is harvested, and commences from the outside.

CHAPTER X.

MOULD OF ONIONS.

Mucor subtilissimus, B.

THE fungi known as *Mucors* or Moulds (*mukēs*, mould) are extremely common on decaying bulbs, fruits, provisions, etc. They are said not to be the immediate cause of decay, but there can be no doubt that they greatly accelerate putrescence when they grow upon exposed or injured places. Sometimes they grow in the inner substance of plants, like the one under description, which has been named by the Rev. M. J. Berkeley, in reference to its extreme smallness and delicacy, *Mucor subtilissimus.*

A species of fungus closely allied to the onion *Mucor* is the common *Mucor mucedo*, L., so frequent on paste, jam, damaged fruit, etc. The onion *Mucor* differs from all its allies, in its extremely small size; it is said to be the most microscopic of all fungi found in Great Britain.

In the *Mucor* disease the whole substance of the neck of the onion near the bulb, and sometimes the bulb itself, is traversed by fine threads of mycelium, and in the midst of this mass of spawn may be seen innumerable black atoms like minute grains of gunpowder. These little grains have been described as fungi under the name of *Sclerotium Cepæ* and *Sclerotium cepævorum*, B.; the nature of *Sclerotia* is described under *Peziza postuma*, B. and Wils. The present *Sclerotia* not only differ from the potato *Sclerotia* in their much smaller, almost microscopic size, but also in their less compact and more filamentous structure. The less compact a *Sclerotium* is, the more readily it will germinate, and in the present instance the

Sclerotium will protrude germ tubes in a few hours if placed in a drop of water. The whole process of growth may be easily watched under the microscope. On germination in water, the filamentous mycelium of which each *Sclerotium* is formed, protrudes, elongates, and branches in a flexuous manner in all directions; this spawn is sometimes jointed and sometimes free from joints, and whilst in water no farther progress is made in growth beyond the protrusion of these threads. As soon, however, as the mycelium reaches the edge of the water, a change takes place, and the branches become furnished on their tips with minute globose heads, technically termed *Sporangia* or spore cases. These extremely minute spherical heads at length become filled with elliptic spores or sporidia (so called because they are produced within a spore case), which, on the natural bursting of the *Sporangium*, or spore case, are set free in the air. The little oval sporidia now soon germinate and reproduce the species. The small mycelial threads protruded from the sporidia are capable of forming little white knots, which at length become, on exposure to the air, the minute black granules termed onion *Sclerotia*.

Now, although these small dark-coloured granules will germinate very readily under favourable conditions in water, it must not be supposed that every example germinates after a few hours' rest. There can be no doubt that this *Sclerotium* condition answers precisely the same purpose in the onion as it does in the very large *Sclerotium* of the potato; that is, it carries on the life of the fungus in a hibernating state through the winter.

Individual fungi vary in their habits of growth precisely in the same way as they vary in their specific characters. No hard and fast line can bind down every individual fungus to specific characters or to habits of growth. For instance, in *Puccinia mixta*, Fl., already described, although nine hundred and ninety-nine *teleutospores* out of a thousand may go to rest for several months,

the thousandth example will germinate at once; and, in the allied fungus of the Hollyhock disease, *Puccinia malvacearum*, Mont., where nearly all the teleutospores germinate as soon as ripe without any rest, it may constantly be observed that a certain number of erratic examples do certainly hibernate. Provisions of this nature are favourable to the existence of fungi, for, if plants were strictly bound by inexorable laws as to habit of growth, they might, by some untoward circumstance, be all suddenly swept out of existence. When unfavourable conditions arise, a species may be kept in existence by individuals of erratic habit.

No doubt the attacks of the onion *Mucor* may be palliated by the destruction by fire of infected plants and refuse. By this means all *Sclerotia* and perennial spawn will be destroyed.

At present *Mucor subtilissimus*, B., has only been recorded as growing upon the cultivated onion, but it doubtlessly grows upon other and allied plants.

CHAPTER XI.

ONION SMUT.

Urocystis cepulæ, Far.

In 1879 a disease of onions appeared in France, known as the "American Onion Smut," *Urocystis cepulæ*, Farlow, a disease which had hitherto been confined to America. Fungi belonging to *Urocystis* are parasitic on living plants, and familiar allies in this country are the bunt of wheat, *Tilletia caries*, Tul.; corn smut, *Ustilago carbo*, Tul.; the common black smuts of violets and colchicum, named *Urocystis violæ*, B. and Br., and *U. colchici*, Tul.; potato smut, *Tubercinia scabies*, B. and Br., and many others. It is probable that we already have this disease in Britain, as onion growers have sorely complained of late of their onions falling into a dusty black mass after harvesting. Whether this fungus is really distinct from the common smut of colchicum, *U. colchici*, Tul., seems somewhat uncertain. The name of the parasite is derived from *uro* to burn, *kystis* a bladder, and *cæpa* the onion plant.

CHAPTER XII.

NEW DISEASE OF GRASS.

Isaria fuciformis, Berk.

DURING the last few years the grass of the southern counties of England has been attacked, as far as this country is concerned, by a curious and possibly new form of disease. Some farmers, however, state that they have noticed the malady for many years past; in one instance twenty years has been mentioned. The disease has appeared chiefly on sandy and chalky soils, and is apparently absent from clay districts. The grasses chiefly attacked by the disorder are the *Festucas*, and notably *Festuca ovina*, L., a valuable pasture grass especially relished by sheep. The fungus which causes the disease does not generally grow on young grass, but the growths appear to be almost peculiar to the old grass, first appearing in September, and continuing in ordinary seasons till the following January. In mild winters the fungus may be seen on the grass till March.

The Rev. M. J. Berkeley originally described this fungus on grass in the *Journal of the Linnean Society for* 1873, vol. xiii. p. 175, under the name of *Isaria fuciformis.* The word *Isaria* is derived from the Greek, and simply means equal, in reference to the simple equal growth of many of the species; and *fuciformis* is founded on the word *phukos*, the Greek name for sea-weed; the word *fuciformis* therefore means, like a *Fucus* or sea-weed. The specific name is an appropriate one, for the resemblance of *Isaria fuciformis*, B., to some of the small linear red sea-weeds is strong. Mr. Berkeley describes the

fungus as growing on some germinating cereal from Mount Gambier in Australia; his description is very brief. He writes: "Pallid, slender, filiform, sparingly branched, branches acute, spores very minute, globular."

FIG. 17.—NEW DISEASE OF GRASS. Panicle of Sheep's Fescue Grass invaded by *Isaria fuciformis*, Berk. Twice the size of nature.

The general appearance of the fungus, as seen growing upon a panicle of sheep's fescue, *Festuca ovina*, L., is shown twice the natural size at Fig. 17. The fungus tufts spring from an effused, mucous, pinkish base of spawn or mycelium, which has a tendency to glue different parts of the grass together as shown at Fig. 18, where three grass stems invaded by the fungus are illustrated five times the natural size. The tufts grow on the stems, leaves, and every other part of the grasses affected, and the growths show a marked tendency when ripe to drop off and fall to the ground. There can be little doubt that this falling of the fungus tufts to the ground is one of the means by which the propagation of the pest is aided. The colour of the fungus is sometimes extremely brilliant, ranging in tint from blood-red to a pink hue similar with pink coral. Were it not for this bright

colour the fungus might be easily overlooked, and it must be remembered that the original description states the plant to be "pallid." A pallid condition of this fungus may therefore possibly be widespread and unnoticed. In some places and seasons the fungus may be always pallid, and so virtually invisible. When the fungus

FIG. 18.
Stems of Sheep's Fescue Grass, with *Isaria fuciformis*, Berk. Enlarged 5 diameters.

exhibits the scarlet colour, the tint appears to be permanent, for no change has been observed in the colour of our dried herbarium examples. In this permanency of colour it resembles the beautiful and closely-allied orange-coloured *Anthina flammea*, Fr., so common on the dead beech leaves of our autumn woods.

In reaching England from Australia this fungus has taken the same course as the *Puccinia* of our hollyhocks and the *Capnodium* of our Thuyas.

The structure of *Isaria fuciformis*, B., is very simple, as is the case with all imperfect fungi. The whole substance of the parasite is one compacted mass of minute cells or exceedingly small transparent bladders, as illus-

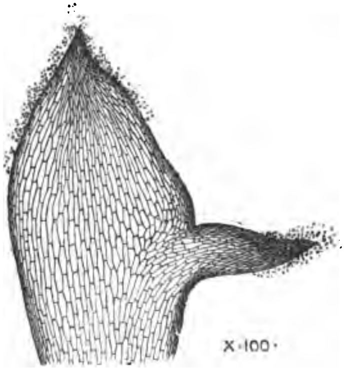


FIG. 19.
Tip of one of the minor branches of *Isaria fuciformis*, B.
Enlarged 100 diameters.

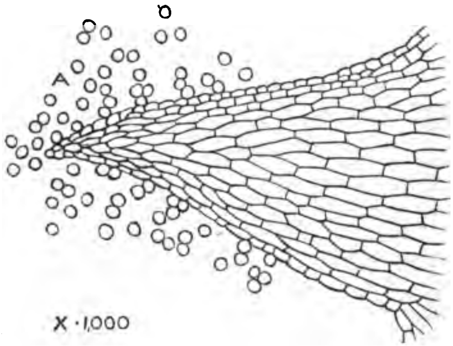


FIG. 20.
Tip of branchlet of *Isaria fuciformis*, B., with conidia.
Enlarged 1000 diameters.

trated at Fig. 19, enlarged 100 diameters; the larger cells occupy the centre of the branches, and the smaller cells form the outside stratum. As the smaller outside

cells gradually reach the tips of the branches they break into innumerable extremely small globose spores or conidia, as shown at A, Fig. 20, enlarged 1000 diameters.

It should be noticed here how closely these *Isaria* spores or conidia resemble in size the *Torrubia* spores at J, Fig. 22, and how extremely small they are as compared with the spores or conidia of the mildew of onions, *Peronospora Schleideniana*, Ung., illustrated to the same scale at C, Fig. 15.

Isaria fuciformis, Berk., is a remarkable fungus, for no other British species of *Isaria* is known to grow on a living plant. Some species grow on dead flowers and dead twigs and stems, others on decaying fungi, one upon cat's dung, and another on dead spiders. Some species of

FIG. 21.
Living Wasp, with fungus growths. Twice the size of nature.

Isaria grow upon dead hymenopterous insects, others grow upon living bees and wasps. One species of *Isaria* grows in this country on dead *pupæ*, another on dead moths; but it is known that these creatures are attacked by the

fungus whilst they are still alive. The illustration at Fig. 21 shows a wasp, twice the natural size, as caught in a living state in this country, languidly flying about with a fungus burden, which may either be a *Stilbum*, as figured by Charles Robin in his *Histoire Naturelle des Végétaux Parasites* (Paris, 1853), or an abnormal form of the *Isaria* condition of the fungus known as *Torrubia sphecocephala*, Kl.

The genus *Isaria* amongst fungi represents an early or larval state of another and more perfect genus of fungi named *Cordiceps*, from the Greek *kordyle*, in allusion to its clublike shape, a genus termed in more modern books *Torrubia*.

Now the species belonging to *Cordiceps* or *Torrubia* (certainly in many instances the perfect state of *Isaria*) are equally curious in their habits with *Isaria* itself; some grow on larvæ and pupæ, even when buried in the ground; two grow on subterranean truffles, and it is remarkable that two distinct species of *Torrubia* attack two equally distinct truffles; another species grows on Wych elm twigs. It is well to mention at this place that *Torrubia* is very closely allied to the fungus named *Claviceps*, which is the perfect condition of the dangerous ergot of rye.

As it is quite possible that *Isaria fuciformis*, B., may be an early condition of a *Torrubia* belonging to an insect or plant host, a brief description of one of the species of *Torrubia* may be useful. The genus *Torrubia* is named in honour of a Spanish botanist who wrote a work on "vegetable wasps." A *Torrubia* parasitic on the truffle named *Elaphomyces muricatus*, Vitt., is fairly common. This curious parasite is named *Torrubia ophioglossoides*, Tul., the specific name having reference to a fanciful resemblance between the head of the perfect fungus and a serpent's tongue. This *Torrubia* is represented, natural size, at A, Fig. 22, attached to its peculiar host or truffle, B. The club-shaped top of the *Torrubia*

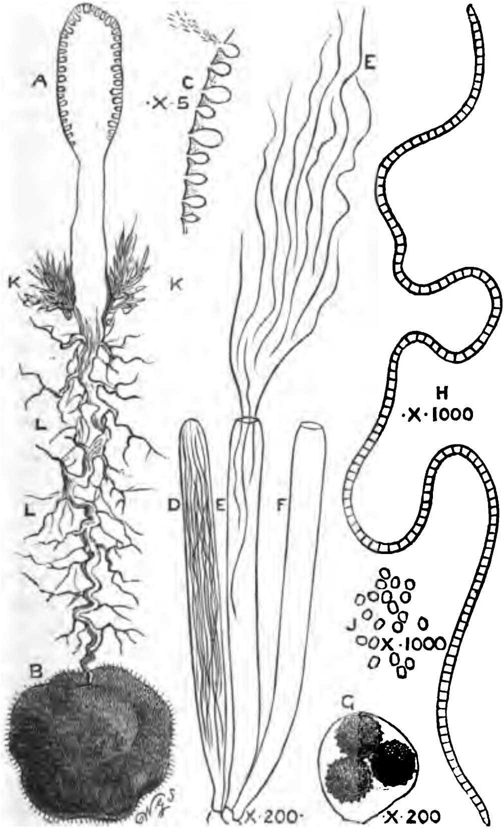


FIG. 22.

Perfect condition of *Torrubia ophioglossoides*, Tul.; parasitic on the truffle *Elaphomyces variegatus*, Vitt.
Natural size, and enlarged 5, 200, and 1000 diameters.

at A is shown in section. This upper part of the fungus is technically termed the *stroma*, meaning a coverlet; and immediately under the surface of this clublike stroma or coverlet are numerous minute embedded flasks, as illustrated. These flasks are termed *perithecia*, in reference to their function, which is to enclose a number of transparent bladders or *thecæ*. The number of contained bladders in each perithecium is about one hundred. At C some of the perithecia embedded in the stroma are enlarged five diameters, and the upper perithecium is shown in the act of discharging the contained spores. If, with the point of a needle, we remove a few of the transparent thecæ, bladders, or asci, and magnify them 200 diameters, we shall see them as at D E F. An ascus is represented, packed with its eight spores, *in situ* at D; the top of the open ascus is shown at E with the eight hairlike spores escaping, and F shows an empty ascus after all the spores have been expelled. If we now leave the *Torrubia* and examine the truffle, we shall find its inner mass densely packed with its own spores, also contained in transparent bladders; but the truffle spores are spherical in form, blackish-brown in colour, and packed in twos, threes, or fours in the asci (not in eights as in the *Torrubia*). Some of the *Elaphomyces* spores in an ascus are illustrated at G, enlarged, like the asci and spores of the *Torrubia*, to 200 diameters.

The spores, or necklace-like chains of sporidia, of *Torrubia ophioglossoides*, Tul., are amongst the most wonderful objects of the vegetable kingdom. One of the eight chains from an *ascus* is enlarged to 1000 diameters at H.

To sum up the characters, the *Isaria* is perfected early in the season, and is capable of reproducing itself by its own spores or conidia, as shown in Figs. 19 and 20. Later in the season the mycelium of *Isaria* often produces a *Torrubia*, A, Fig. 22; and the latter plant, instead of producing free, dustlike spores from the naked apex of its branches, as in the *Isaria*, produces spores or sporidia in the form of long chains enclosed in transparent flasks,

these flasks being enclosed in larger bladders termed *perithecia,* and the whole embedded in the club-end or stroma of the *Torrubia.* It is obvious that in the latter position the sporidia are well protected by three different enclosing walls, one within the other, and there can be no doubt that these contrivances aid the contained spores in tiding over vicissitudes of rain, drought, and frost during winter. When the spring comes the stroma softens, the mouths of the perithecia open, the asci sail out and burst, and the chains of spores are set free in the air. These chains speedily fall to pieces, as illustrated at J, enlarged 1000 diameters, and each fragment or sporidium on germinating is capable of producing, not a *Torrubia* but an *Isaria.* How small these numerous reproductive bodies are may be judged from the fact that it would require two hundred millions of them to cover a superficial inch. Every plant of *Torrubia ophioglossoides,* Tul., sets free at least ten millions of these reproductive bodies every spring.

Before dismissing *Torrubia ophioglossoides,* Tul., a curious fact regarding it may be mentioned. As it is parasitic on an underground truffle named *Elaphomyces muricatus,* Vitt., the question presents itself, How can the exceedingly minute spores of the *Torrubia* reach the subterranean truffle, buried, as it is, some four or five inches beneath the ground, in places often thickly covered with brambles, ferns, and moss? The explanation of this phenomenon is: The spawn from which the *Torrubia* springs grows in the first instance, over a common moss named *Mnium hornum,* Hedw., sometimes given as *Bryum hornum,* Sw., illustrated natural size at Fig. 23. The spawn or mycelium of the *Torrubia* is yellowish, and when this yellow spawn once fixes on the moss it goes from leaf to leaf, from stem to stem, and from root to root, till sometimes a large patch of this common moss is covered with the yellow sticky threads of the curious *Torrubia* mycelium, which is really now running from plant to plant in search of truffles.

It is an above-ground truffle-hunting mycelium. If there are no truffles in the wood, the mycelium, of course, perishes ; but in some other wood where the moss grows, the truffles will certainly occur. When the moss does grow in the same wood with the truffle, the parasite is certain to descend by the roots, and so find the subterra-

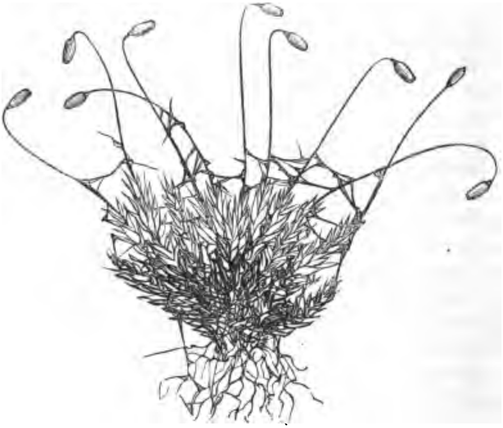


FIG. 23.
Mnium hornum, Hedw., invaded by the mycelium of *Torrubia ophioglossoides*, Tul.

nean *Elaphomyces.* The truffle usually grows some four or five inches beneath the surface of the ground, and seldom so near as two inches, as shown in illustration at Fig. 22, where KK shows the ground line, and LL the spawn belonging to the *Torrubia* connected with the truffle below at B.

It is a curious fact that field mice, and probably several other small mammals, are extremely fond of the truffles named *Elaphomyces* (from *elaphas*, an elephant, and *mukes*, a fungus), and these little animals are continually

scratching about for the truffles. There is a kind of race then between the mammal and the mycelium for the underground fungus.

Botanists, who search for truffles always know where the *Elaphomyces* is to be found by looking for the spawn of the *Torrubia* on the moss. The spawn-covered moss points out the position of the truffle, as surely as the bird named the Great Honey Guide, *Indicator major*, Steph., leads hunters to bees' nests in Africa.

A closely allied species of *Torrubia*, named *T. militaris*, Tul. (in the older books *Cordiceps* or *Sphæria*), of bright scarlet colour, is extremely common in Britain in the autumn and early winter, growing from dead pupæ buried in the ground. The fungus resembles a scarlet club, about an inch or an inch and a half high. It grows in pastures and grassy places, where larvæ have buried themselves. The mycelium grows within the body of the pupa, and the scarlet club commonly grows from the first joint behind the head. The anatomical characters of *T. militaris*, Tul., agree generally with *T. ophioglossoides*, Tul.

The *Isaria* disease possesses considerable interest on account of the popular belief that it is capable of greatly injuring, and indeed of killing the cattle that feed upon the grass infected with it. In September 1880 an instance occurred where two cows died in an *Isaria*-infected district from an affection of the lungs; and when a post-mortem examination was made it was found that the lungs were covered with a fungus-like growth, not unlike, it is said, the appearance presented by the throat in diphtheria. The veterinary surgeon who conducted the examination declared his opinion that the fatal ailment had been contracted from the *Isaria*-infected grass. The same medical practitioner is said to have fed two rabbits on infected grass only, and that they both died therefrom. It is, perhaps, unnecessary to say, that these cases are far from being proved. At the same time, it would not be wise to immediately say that such cases are impossible. In favour

of the doctor's view it may be called to mind that several members of the genus of fungi to which *Isaria* belongs, grow naturally on living animals.

It is not usual for fungi to grow on living or, indeed, dead animal material, yet botanists are familiar with several such examples other than the ones already cited. The familiar fungus of the salmon disease, *Saprolegnia ferax*, Kutz., is one, and the white dusty fungus named *Empusa muscæ*, Cohn., so common on flies on our window panes in autumn, another. This is said by some observers to be merely a second condition of the *Saprolegnia*. The ringworm fungus *Oidium porriginis*, Mont., is another example; *Microcera coccophila*, Desm., a parasite of *Cocci*, —insects of the American blight class,—is a third; *Onygena equina*, Pers., which grows on the hoofs of dead horses, is a fourth, and the list might be greatly extended. Fries has described an Agaricus, named by him *A. nauseosus*, growing on the carcass of a wolf, and *A. ostreatus*, Jacq., has been seen in this country by Mr. C. B. Plowright growing on the dead body of a stranded whale; *Onygena apus*, B. and Br., is not uncommon on bones. These instances are not mentioned with the view of showing that *Isaria fuciformis*, B., is capable of killing cattle, but to indicate that other and, in some instances, closely allied fungi can support themselves on living and dead animal substances.

It is extremely difficult to suggest any means for the destruction of the *Isaria*, partly because the fungus falls from the grass to the ground on the slightest touch, and partly because so very little is known of the fungus or its habits. The whole subject requires investigation. Some crops might be saved by removing the greater part of the grass before September, or by the substitution of some crop on which the *Isaria* could not grow. As humidity probably favours the growth of the pest, good and careful drainage might prevent its spreading. No doubt many insects carry the conidia, or spores, from place to place

on their bodies, and so infect previously untainted districts.

Towards the end of 1883 Mr. Greenwood Pim, M.A., F.L.S., and Dr. E. P. Wright, A.M., F.L.S., detected *Isaria fuciformis*, B., growing in a new position, viz. on grass belonging to a silo at the Albert Model Farm, Glasnevin, Co. Dublin. Mr. Pim kindly forwarded examples to us, and he soon afterwards published an illustrated account of the discovery in the *Gardeners' Chronicle* for 22d December 1883. Mr. Pim's examples were remarkable for being infested with a parasitic fungus, and one apparently till now undescribed. The parasite grows on the *Isaria*, breaks up its tissues, and more or less absorbs its crimson colour. The parasite is a *Saprolegnia* allied to *S. ferax*, Kutz., of the salmon disease, but different in many important characters.

The new parasite, which may be termed *Saprolegnia philomukes*, W.Sm. (from *sapros*, decayed; *legnon*, a fringe or border; *phileo*, I love; and *mukes*, a fungus), is illustrated at Fig. 24, enlarged 400 diameters. The circular bodies are sporangia, zoosporangia, or spore-cases of unusually large size, and filled with small motile spores or zoospores. In the largest sporangium illustrated it will be seen that the zoospores are germinating within the sporangium, and protruding their germ tubes through its gelatinous wall. A remarkable character in this parasite is found in the septate or jointed mycelium, an unusual character in the *Saprolegnieæ*, in the mycelium carrying numerous conidia, as at AA, and in the sporangia and mycelial threads often becoming confluent, as at B, C. In the Dublin examples, the sporangia were so abundant that all parts of the *Isaria* threads were covered, they were so crowded together that they took pentagonal and hexagonal instead of circular forms. Many sporangia were sessile, or intercalated in the mycelium, whilst others were shortly stalked. Antheridia (male organs described under the fungus of the potato disease), as at D, were rare: the jointed my-

celium formed a dense transparent stratum over the host plant. In some places the parasite was colourless, like

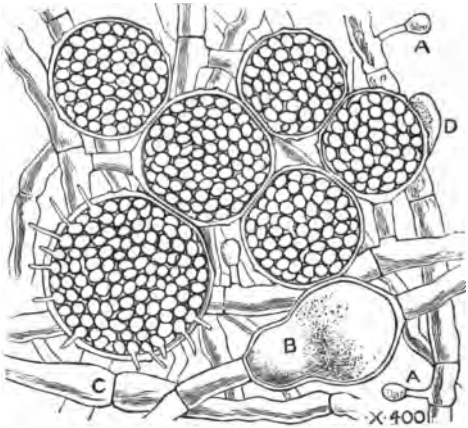


FIG. 24.
Parasite of *Isaria fuciformis*, B. ; *Saprolegnia philomukes*, W.Sm.
Enlarged 400 diameters.

the better known species of *Saprolegnieæ;* in other places it was rose-coloured, from its absorbing the colour of the red *Isaria.*

Saprolegnia philomukes, W.Sm., zoosporangia, very large, thick-walled, sessile, shortly stalked, or intercalated in the mycelium, sometimes confluent with each other, all bearing zoospores, which often germinate whilst still *in situ.* Antheridia elongated, rare ; mycelium profusely septate, somewhat torulose, filled with colourless or rose-coloured protoplasm, and bearing many small abortive sporangia or conidia.

We have seen a similar plant on fungi, with oospores as well as zoospores.

CHAPTER XIII.

STRAW BLIGHT.

UNDER the name of Straw Blight agriculturists are well acquainted with a peculiar diseased condition of the living

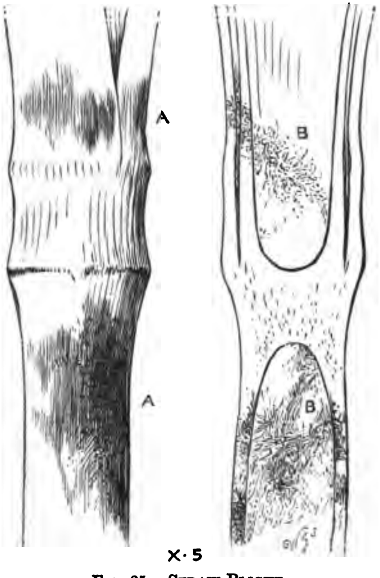


FIG. 25.—STRAW BLIGHT.
Fragments of diseased Wheat Stems. Enlarged 5 diameters.

stems of wheat, barley, rye, and other grasses, which

commonly makes itself apparent in midsummer by the impoverished appearance of the flower-spike. Sometimes the disease occurs in spring, and then it often proves fatal to the plants attacked.

Straw blight is caused by the attack of a fungus on and in the straw at a point close to or very near the ground. The fungus growth seldom reaches so far up the stem as the second or third joint, the attack being more frequent below the first joint from the root, and close to the ground. It is superficially recognised by brownish disease-spots outside the straw, as illustrated at AA, Fig. 25, enlarged 5 diameters; but if the straw is carefully cut longitudinally with a sharp knife, it will be seen that the disease is by no means superficial. The disease-spot goes through the solid wall of the hollow stem, and in typical examples the hollow part will be more or less filled with loose flocculent material, as illustrated at BB. This flocculence is really the mycelium or spawn of a fungus. Having now obtained a clue to the nature of the so-called blight, an excessively thin and transparent atom must be sliced off from the exposed surface of one of the brown disease-spots with a lancet, and this slice highly magnified. If we enlarge this atom 200 diameters, and examine at it as a transparent object under the microscope, we shall probably see it as illustrated at Fig. 26. The base of the illustration shows the cells of the solid part of the straw in transverse section, whilst the main part of the illustration shows the stem in longitudinal section: the bottom, in fact, represents the base of the minute transparent atom sliced off. We now see the spawn threads distinctly; they are transparent or nearly so, and so fine and attenuated that (as may be seen by the thinner lines of the illustration) they are less in thickness than the walls of the microscopic cells, of which the straw stem itself is built up. They will be seen to branch, and apparently pierce the cell-walls both vertically and horizontally, and in old examples to almost fill the hollow of the stem. A close examination

will show that in a few places there are transverse joints, stops, or *septa* in the threads of spawn, as illustrated in the separate thread on the left of illustration, enlarged

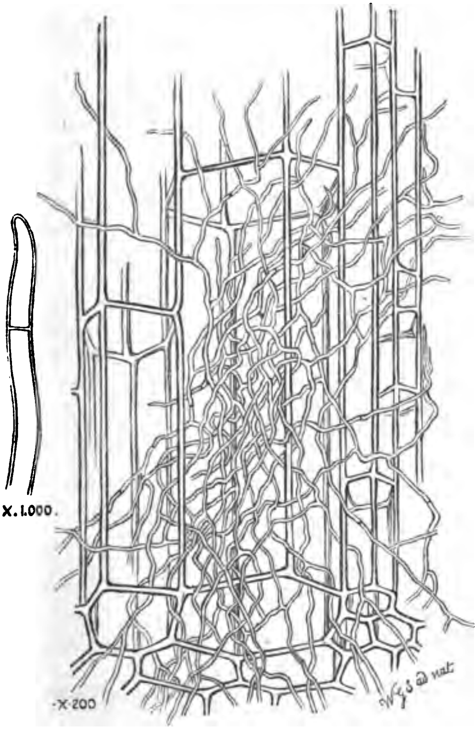


FIG. 26.—STRAW BLIGHT.
Fragment of diseased Wheat Stem.
Enlarged 200 diameters.

1000 diameters. It is a most unusual thing to see any fungus spawn without these stops, although they are

much more common in some fungi than in others. The stops or transverse partitions represent a slight temporary rest in the growth of the threads. For a brief period the spawn has exhausted its powers of extension, and a septum or transverse wall is formed across the thread, and from this point a new and vigorous start is commonly made.

As the fungus-spawn of straw blight apparently possesses the power of piercing the walls of the cells of which the straw is built up, it follows that all parts of the straw are liable to be infested and pierced. This piercing causes a fatal injury to the cell-structure, and every farmer knows that if his plants are attacked by this blight whilst the crops are still young, the growth will be stopped. The walls being pierced the flow of sap is arrested, and the upper part of the plant perishes from want of nutriment. In the older plants the stem is often observed to throw out new roots from the joint above the diseased part; and if these new roots are able to reach the earth, they sometimes carry on the life of the plant in place of the old roots, which are more or less cut off from the stem. The new roots are never quite effectual in keeping up the supply of food and life, and a stem once attacked by straw blight is said to never entirely recover.

It is curious that no one has at present recorded the perfect form of the fungus which must, under favourable circumstances, arise from this spawn. Such a barren condition in mycelia is not uncommon; the fact often holds good with fungi that there is an enormous development of mycelium but no perfect fungus. There are many more or less barren mycelia well known to botanists, such as the orange-coloured fungoid growths known as *Ozonium*, *Byssus*, *Rhizomorpha*, and many others. In some instances, as in the grape mildew, the spawn proceeds one step farther and produces what is termed an *Oidium*, which, like the *Isaria* last described,

is really a kind of larval condition of some more perfect fungus, the ultimate form of which has perhaps never been seen, or, if seen, has not been recognised. The nature of *Oidium* is described under the *Oidium* of the turnip and under grass blight, *Erysiphe graminis*, D.C.

Grasses both wild and cultivated, living and dead, are subject to the attacks of so many fungoid assailants that it would be almost useless to guess at what the perfect form of the fungus of grass blight might be. The *Gramineæ* and *Cyperaceæ* are unusually subject to the attacks of fungi. Many of the pests are, however, superficial, and do not possess the power of piercing and traversing the cellular tissue. All, however, are objectionable, as they not only reduce the crop, but more or less lessen its value as food. The phenomenon of piercing the cells in the fungus of straw blight reminds us of the corrosive mycelium of the fungi of the potato disease found under *Peronospora.* Several species of *Fusisporium* have been detected on cereals, but the mycelia of these as seen by us do not well agree with the spawn of straw blight. A fungus named *Fusisporium insidiosum*, Berk., a parasite of the grass named *Agrostis pulchella*, Kunth., is by no means well known, and requires further attention.

The loss to farmers from straw blight ranges from one-half to one-fiftieth part of the crop, according to the virulence of the attack ; but the blight is erratic in its appearance, sometimes temporarily vanishing, and then returning with great activity. Like some other mildews and blights, but not all, straw blight is fostered by a continuance of warm, wet weather.

As the growth of straw blight is promoted by moisture, it seems probable that if the quantity of water about our cereal crops in wet seasons could be lessened by perfect drainage, the amount of destruction from straw blight would be less. Wheat and barley are not generally

grown in wet, peaty places, yet in the alluvial flats belonging to some rivers, and where good drainage is difficult, these crops may often be seen. No doubt perfect drainage would considerably lessen the losses commonly entailed by attacks of straw blight.

CHAPTER XIV.

SURFACE MILDEW OF TURNIPS.

Oidium Balsamii, Mont.

THE mildew of turnips, named *Oidium Balsamii*, Mont., is often confounded with the true putrefactive mildew of the cabbage tribe, named *Peronospora parasitica*, Pers. The two are indeed so much alike to the unaided eye that it is often impossible for even an experienced observer, without a lens, to distinguish one from the other. As if to make the subject still more involved, it frequently happens that the two fungi grow in company on the same host plant. They are, however, wholly distinct from each other, both in habit and structure.

The name *Oidium* is derived from the Greek *oon*, an egg, and *eidos*, resemblance, and refers to the usual egg-shaped form of the spores or conidia. In the present instance the generic name is not very appropriate, for the conidia are somewhat barrel-shaped. The specific name *Balsamii* was given in honour of Balsamo, a Milanese gentleman, who first noticed the species. When first detected the fungus was growing on a Continental species of Mullein, named *Verbascum montanum*, Schrad. We have this plant in our gardens, but the fungus is more common here on the Black Mullein, *Verbascum nigrum*, L.; it also grows on cultivated strawberries. In the latter case the fungus makes its first attack on the leaves, and then speedily invades with increased vigour the flowers and footstalks, ultimately inducing the wretched appearance so well known in connection with grape vines when attacked by the allied fungus named

Oidium Tuckeri, B. Although several species of *Oidium* have been recorded from Scotland, *Oidium Balsamii*, Mont., has not yet been detected there. If it really grows so far north, it could hardly have been overlooked, as it is a remarkable species.

Oidium Balsamii, Mont., first attracted attention as a pest of turnips in September 1880, when Prof. James Buckman, F.L.S., of Bradford Abbas, Dorsetshire, saw the fungus growing in such profusion over hundreds of acres of Swede turnips that the boots and clothes of persons walking through the turnip fields were whitened with the spores. Until 1880 the fungus was not supposed to be common in Britain ; and it is remarkable that the same fungus should be found growing upon three different natural orders of plants, viz. the *Scrophulariaceæ*, the *Rosaceæ*, and the *Cruciferæ*. Some farmers say the plants produced from early sown seeds are the most subject to this mildew. It first attacks the lowermost leaves, and then quickly covers every part of the affected plant. The presence of this pest, which is now known to be a common and injurious mildew of turnips, generally foreshadows a deficiency of roots.

To the unaided eye the foliage of affected Swedes is white on both sides when attacked by the mildew ; but when seen under a low power of the microscope this white coating resolves itself into a dense felted mass of spider-web-like threads, dotted all over with innumerable barrel-shaped spores.

The higher powers of the microscope are required to show the exact nature of the *Oidium* of turnips. A minute fragment must be cut from an infected place on a turnip leaf, and from this fragment an exceedingly thin transparent slice should be cut. When placed in a dry state under the microscope it must be specially noticed that the fungus growth is wholly superficial, and that no spawn threads belonging to the *Oidium* occur within the leaf. In this respect the *Oidium* essentially differs from

the *Peronospora*, next described in this work. When a minute slice, as just mentioned, is examined under the microscope and enlarged 400 diameters, it will be seen as illustrated at Fig. 27. The fungus grows on both surfaces of the leaf, and springs in both positions from a

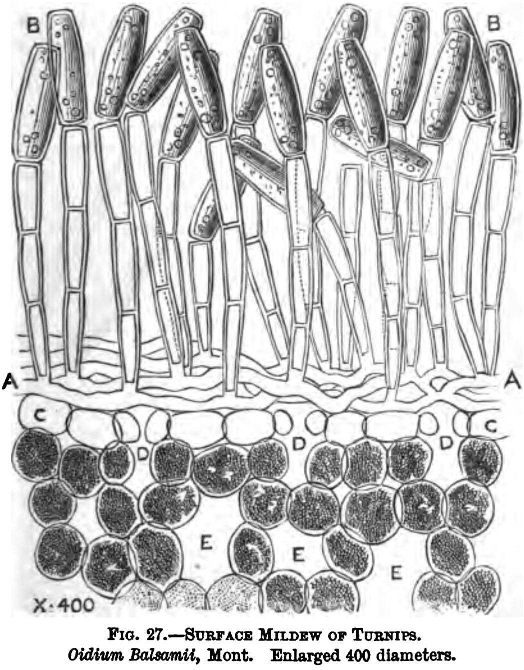


FIG. 27.—SURFACE MILDEW OF TURNIPS.
Oidium Balsamii, Mont. Enlarged 400 diameters.

dense stratum of matted and jointed spawn, as shown at AA. From these horizontal spawn-threads arise innumerable vertical club-shaped growths, each club being furnished with three joints and surmounted by a barrel-shaped spore or conidium, as shown at BB. The cells at

CC, represent the lower cuticle of the leaf, whilst the openings at D D D, show the stomata or organs of transpiration. It will be observed that the spawn of the invading fungus does not enter the stomata or traverse the intercellular spaces of the leaf, such as are shown at E E E. The barrel-shaped spores or conidia of this fungus are so numerous that more than 10,000 are produced on every square inch of leaf surface, and every

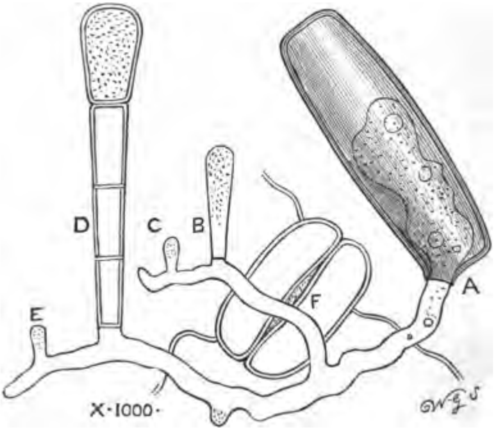


FIG. 28.
Oidium Balsamii, Mont.
Germinating Spore enlarged 1000 diameters.

turnip leaf will carry on its two surfaces a million or more of these reproductive bodies.

The spores germinate very readily, for they have only to be dusted on to clean glass and kept moist, under a bell-glass, when they will be seen to germinate at once as illustrated at Fig. 28, enlarged 1000 diameters. The germinating conidium bursts at one corner as at A, and from this corner the contained protoplasm or vital

material streams in threadlike form, and from this thread new clubs immediately arise. Four of these bodies, in different stages of growth, are shown at B, C, D, and E. The surface of one of the organs of transpiration is shown at F, over the opening of which a thread of mycelium has passed.

This *Oidium* chiefly injures the turnip by weaving a thick web of mycelium over the organs of transpiration. The spawn effectually stops the passage of watery vapour from the interior of the affected plant, and so puts an end to one of its chief vital functions. The general result is an arrest of growth, and ultimately a poor crop of roots.

Oidium Balsamii, Mont., is supposed to be an early condition of some more perfect fungus, probably an *Erysiphe*, such as one sees on the hop, on roses, on mildewed grass, and on peas. The two latter species of *Erysiphe* are referred to in detail farther on in this work. Important as this *Oidium* is to agriculturists, no one at present has worked out its life history or knows whence it comes, where it goes, what other form it takes, or how it hibernates through the winter. The fungus is more prevalent when a humid September follows on a dry August.

CHAPTER XV.

PUTREFACTIVE MILDEW OF TURNIPS AND CABBAGES.

Peronospora parasitica, Pers.

THE fungus which causes this disease frequently accompanies *Oidium Balsamii*, Mont., already described, but it differs entirely from it both in anatomy and nature. When a *Peronospora* infected leaf is examined with the unaided eye, the thick white bloom on both sides of the leaves, as in *Oidium Balsamii*, Mont., is never seen. The *Peronospora* appears as a thinner, more scattered bloom on the under side of the leaves only, and generally borders pallid, discoloured, and decomposed patches on the leaf. A profuse growth of *Peronospora* is not to be distinguished from a slight growth of *Oidium*, without the aid of a lens.

If a small piece of the leaf of a turnip infected with *Peronospora parasitica*, Pers., corresponding in size and thinness with the *Oidium* infected slice already described, is placed under the microscope and examined, it will be seen, if enlarged to a scale one-half that of the last, viz. 200 diameters, like the drawing at Fig. 29. The first point to be especially noticed is, that the spawn which gives rise to the fruiting threads of the *Peronospora* mildew is inside the leaf, as shown between the letters A and B. These letters indicate the upper and lower surface of the leaf. The spawn threads are stout as compared with many other mycelia, and have very few septa or stops; they are notably furnished with numerous *haustoria*,—from *haustor*, a drawer,—or little suckers, as shown at C. The suckers attach themselves to the

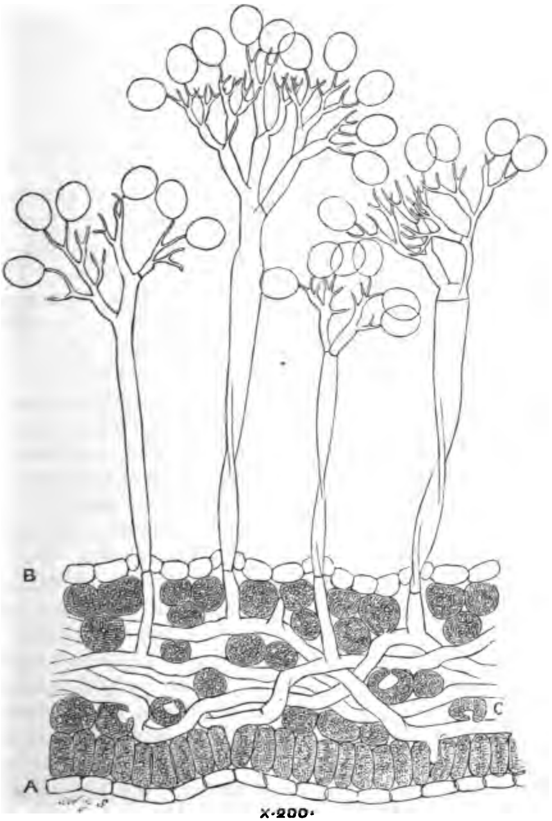


FIG. 29.—PUTREFACTIVE MILDEW OF TURNIPS AND CABBAGES.
Peronospora parasitica, Pers. Enlarged 200 diameters.

constituent cells of the leaf, and the mycelium sets up decomposition in every part of the leaf with which it comes into contact.

The upper surface of a turnip leaf is shown at A, and the lower surface at B, and it will be seen at once that the spawn threads within the leaf are of too great a diameter to emerge through the little lancet-shaped orifices of the stomata. When the fungus threads from within approach the little openings of transpiration in their growth outwards, they slightly contract in diameter, form a stop or joint, and then, instead of emerging through the stomata with a pointed end, they present a chisel edge to the mouth of the pore, which exactly suits the shape of the little lanceolate opening. This mode of emergence is shown, enlarged 1000 diameters, on the left hand lower illustration of Fig. 30. The stems of the fruiting threads are therefore not truly cylindrical, but, when seen in section, present a flattened oval form as illustrated. As the stem now gradually grows upwards it usually twists round once upon itself. This twisting habit is slightly retained by all the numerous branches and branchlets of the fungus. The upper part of each stem of *Peronospóra parasitica*, Pers., is very much branched and rebranched, and each little branchlet carries a comparatively large ovate, almost globular spore, as shown, enlarged 1000 diameters, in Fig. 30. The spores or conidia usually germinate by bursting at the side, and the protruded vital material or germ tube has the power of piercing the cuticle of cruciferous plants. Although represented in the drawing as growing in an upright fashion, the real growth of every *Peronospora* is of course downwards from the under surface of the leaf. Now, if the illustrative drawing is turned upside down to present the *Peronospora* in a really natural manner, the resemblance of the fungus to a minute bunch of grapes is a striking one. From this resemblance the genus now termed *Peronospora* was for many years known as *Botrytis*—from *botrys*, a bunch, in reference to the resemblance to a bunch of grapes.

No zoospores have been detected in this species, but,

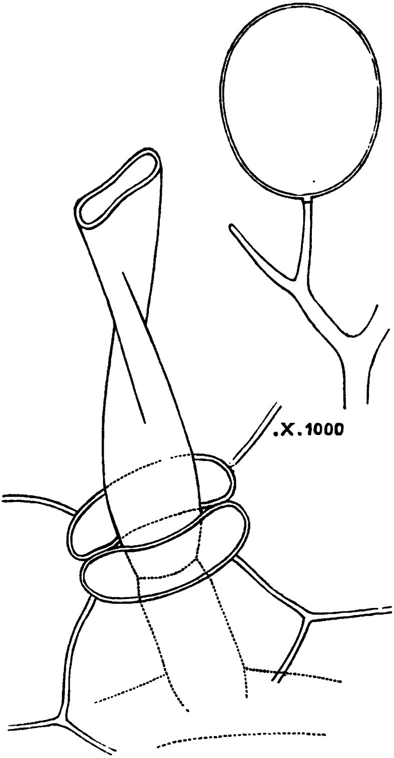


FIG. 30.
Peronospora parasitica, Pers.
Spore and Conidiophore emerging through an organ of transpiration.
Enlarged 1000 diameters.

like the *Peronospora* of the potato, it produces *oospores* or resting-spores ; the resting-spores act as seeds, and carry on the life of the fungus in a hibernating state through

the winter. The resting-spores, which were first detected in turnips in 1849 by Mr. C. Edmund Broome, M.A., F.L.S., of Batheaston, Bath, were figured by Dr. Montagne, and named by him (like the similar bodies found in diseased potatoes) *Artotrogus.* The resting-spores or oospores of *Peronospora parasitica*, Pers., are often extremely common in rotten turnips and mangel-wurzels, as found in the fields in autumn. These roots are often destroyed by a combined attack of the putrefactive mildew of turnips and the fungus of club-root, described further on in this work. In order to see the resting-spores, portions of the brown decayed substance of the diseased root should be looked over till the oospores are found. The less ripe examples are smooth outside or slightly granular, and the more mature specimens are beautifully echinulate, as illustrated, enlarged 400 dia-

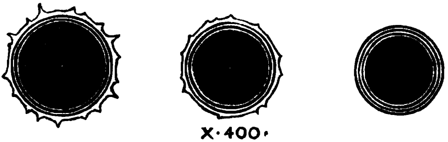


FIG. 31.
Resting-spores or Oospores of *Peronospora parasitica*, Pers.
Enlarged 400 diameters.

meters, at Fig. 31. Dr. Montagne and Mr. C. E. Broome first observed this fact in 1849, for on the original drawing in the possession of the Rev. M. J. Berkeley the smooth form is labelled "*sp. jun.*," and the nodulose form "*matur.*" In colour the resting-spores are yellowish-brown. The examples found by Mr. Broome in 1849; those illustrated by Professor de Bary in 1863, *Ann. Sc. Nat.*, 4 ser., vol. xx.—again by him in the *Beitrage zur Morphologie und Physiologie der Pilze*, 1881, pl. 1, under the name of *Artotrogus hydnosporus*, Mont. (see also *Gardener's Chronicle*, April 26, 1884, p. 544); and the specimens shown at Fig. 31, agree in size, character, and colour.

The resting-spores of this fungus have also been detected in the wallflower, *Cheiranthus Cheiri*, L.; the Shepherd's-purse, *Capsella Bursa-pastoris*, D.C.; *Camelina sativa*, Cranz., and in other plants.

Peronospora parasitica, Pers., not only grows on the wild and all the cultivated varieties of the cabbage and turnip, *Brassica oleracea*, L., and *B. campestris*, L.; but it often grows on Whitlow Grass, *Draba verna*, L., and on the Shepherd's-purse, *Capsella Bursa-pastoris*, D.C., in company with one of the white-rust fungi named *Cystopus candidus*, Lev., described farther on. It also grows on Garlic Mustard, *Alliaria officinalis*, D.C.; Pennycress, *Thlaspi arvense*, L.; Tower mustard, *Arabis perfoliata*, L.; Coral root, *Dentaria bulbifera*, L.; *D. heptaphyllos*, Clus.; *Neslia paniculata*, Des.; Hairy Bittercress, *Cardamine hirsuta*, L.; Narrow-leaved Bittercress, *C. impatiens*, L., and other plants.

The many common weeds just mentioned act as nurse plants for the putrefactive mildew of our turnips and cabbages. The fungus lives through the winter in a hibernating state not only in rotten turnip and mangel roots, but in the decaying remains of such extremely common weeds as the Shepherd's-purse and other worthless plants. It is obvious, then, that it is not only desirable to burn all fungus-infected turnip and cabbage material, but as far as possible to keep the fields and hedgerows clear from the cruciferous weeds just mentioned. It may be answered that it is impossible to keep down the weeds and burn the decaying cruciferous rubbish. This may be partially true, but the moral to be drawn from the life history of this fungus is, Do not let putrid refuse and worthless and dangerous weeds interfere more than is necessary with the healthy growth of food-plants.

CHAPTER XVI.

WHITE-RUST DISEASE OF CABBAGES, ETC.

Cystopus candidus, Lev.

THERE is no more familiar parasite of cruciferous plants than the fungus of White Rust, *Cystopus candidus*, Lev. The generic name is derived from *kystis*, a bladder, and *pous*, a foot; *candidus*, of course, refers to the white colour of the fungus; the name is intended to indicate the white pustular appearance of the fungus on the attacked plants. White rust is extremely common on cabbages, excessively so on the common Shepherd's-purse, *Capsella Bursa-pastoris*, D.C., and many other cruciferous weeds and garden flowers. The appearance of the fungus is known to every one who has walked in a kitchen garden. Cabbages and cauliflowers are seen with their leaves and stems swollen, distorted, and spotted with white streaks and blotches, as if sprinkled over with whitewash. If typical examples of the parasite are carefully examined on invaded leaves, it will be noticed that the white splashes are really somewhat elongated swollen pustules, often arranged in a concentric or spiral manner, and measuring half an inch or more across. On the leaf stalks and flower stems the pustules are disposed in a more irregular manner. The parasite invades every part of the host plant above ground, sometimes sweeping off every seedling in the earliest stages of growth, at other times attacking the flowers, and so stopping the production of seeds. The fungus, in whatever form it appears, reduces and damages the produce of the plants attacked. Experienced observers can detect the presence of white rust long before the

white pustules are visible, by the swollen and distorted appearance of the leaves and stems, caused by the presence of the spawn of the parasite within the plant. As in *Peronospora*, the mycelium of *Cystopus* traverses the host plant by the intercellular passages. The spawn threads resemble the mycelium of *Peronospora parasitica*, Pers., in being provided with suckers which become affixed to the constituent cells within the leaves and stems of the host. When the white pustules are examined with a microscope they are found to be not dissimilar in character although different in colour from the pustules belonging to *Puccinia mixta*, Fl., already described, or of the rust fungus of corn, *Uredo linearis*, Pers., described further on. Instead, however, of simple red Uredo spores or compound blackish Puccinia spores being found within the pustules, chains of almost colourless round or ovate spores or conidia are seen in the white-rust fungus. Chains of conidia or spores belonging to *Cystopus candidus*, Lev., are illustrated in different stages of growth, enlarged 400 diameters, at A, Fig. 32. The fungus grows beneath the epidermis of the plant after the manner of *Puccinia mixta*, Fl., already described; the pustules produced by the white-rust fungus are, however, very much larger than the blisters of the *Puccinia*. The spores or conidia grow in chains, a fact first pointed out by the Rev. M. J. Berkeley, in the *Journal of the Royal Horticultural Society*, vol. iii., p. 269, 1848. The spores or conidia are formed in *Cystopus* in the following manner:—At first simple clublike growths are produced as at B; a constriction forms towards the apex of the club, which speedily takes the form of a joint or septum as at C; in the process of growth another constriction occurs as at D, which in turn speedily becomes a septum or joint. As this process is repeated each club at length supports a short chain of conidia, each conidium being attached to the conidia next in order by joints as at DD. When large numbers of conidia have been produced in this

manner in the disease pustules, the epidermis of the host plant bursts in an irregular manner, and the conidia are set free. Each conidium is filled with finely granulated protoplasm or vital material.

When the conidia approach maturity in damp air or water, the interior substance of each may be seen divided into a definite number of portions, generally from five to eight; each portion presenting a pentagonal or hexagonal form bounded by a white line, precisely in the manner of the conidia of the fungus of the potato disease described

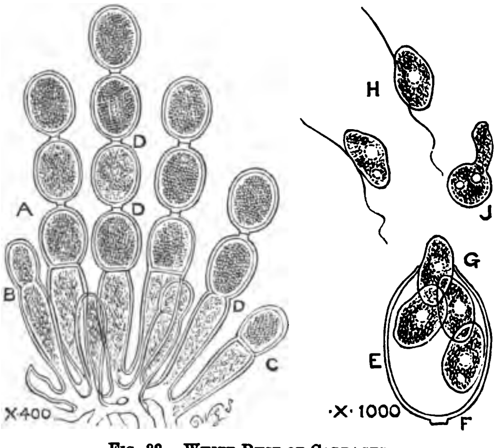


FIG. 32.—WHITE RUST OF CABBAGES.
Cystopus candidus, Lev. Enlarged 400 and 1000 diameters.

farther on in this work. Each of the contained portions within the conidium is now really a secondary spore, and the body which was at first a simple conidium has now become a sporangium or spore case—technically, in this instance, called a zoosporangium, or case containing zoospores or spores endowed with an animal-like motion.

If we take a perfectly ripe conidium, sporangium, or

zoosporangium, and enlarge it 1000 diameters, we shall see it as at E, Fig. 32 ; the former point of attachment is seen at F, and the sporangium is shown in the act of discharging its differentiated contents, in the form of zoospores, from its apex. These secondary spores were at first the polyhedric contents of the sporangium ; but as they emerge in water or on any damp surface the angles become rounded, and they are at last expelled as minute ovoid bodies as illustrated at G. At first these small secondary spores or zoospores remain immovable at the mouth of the burst sporangium ; soon, however, they begin to slightly oscillate, and two excessively attenuated hairlike cilia are developed from beneath as at H. At a special moment the foremost cilium is distended in a straight line as shown, whilst the hindermost cilium at the same time suddenly quivers, and the zoospore sails away over any moist surface, as if endowed with animal life. Each zoospore exhibits within one or more lustrous, perhaps contractile, vacuoles.

The phenomena just described can only be seen when a zoosporangium of the white-rust fungus, has been placed in water upon a glass slide, and viewed under a cover-glass with a high power of the microscope. In dry air no differentiation of the contents of the conidium takes place. It is certain that rain, dew, or moisture of some sort is essential for the bursting of the sporangia and the expulsion of the zoospores. The bursting, as seen in water, under the microscope takes place in an hour or two after immersion; the conidia retain the power of producing zoospores for about a month. The zoospores are able to swim about for several hours ; their cilia then vanish, the zoospore retakes a globular tailless form, bursts as at J, produces a germ tube, and this germ tube is then a spawn thread of white rust capable of producing a new series of clubs capped with zoospore-bearing sporangia.

It is obvious from the above description that the white-

rust fungus is carried from one leaf to another, from one plant to its neighbouring plant, and from weeds to food-plants, in damp, rainy, or misty weather, by the microscopic zoospores sailing about over moist surfaces. There can be no doubt that they are also carried about in damp air, in currents of wind, and that birds, insects, and other animals help to carry the living conidia and zoospores from place to place.

As a rule conidia, zoospores, germ tubes, and fungus spawn are very liable to perish; too much dryness, a superabundance of moisture or frost, will quickly destroy them.

Three questions now present themselves to us—How does the white-rust fungus tide over the winter? Where is it hidden? How does it suddenly reappear in the spring? In the case of many plant diseases, as in the surface mildew of turnips, *Oidium Balsamii*, Mont., already described, no one is able to answer such questions; but with the white-rust fungus and several of its allies the knowledge has been obtained, and a satisfactory answer can be given. It has been already stated that the spawn or mycelium of *Cystopus* grows within the leaves and stems and burrows amongst the intercellular spaces of the host plant. It not only bears the chains of spores already described, which, when ripe, are blown away by the wind, but it carries other bodies within the substance of the leaf. These latter organs roughly answer to the pistils and anthers of flowering plants. The first bodies are female, and are termed *oogonia;* these are large globular cells in which the female reproductive bodies, or oospheres, or sometimes zoospores, are formed. They generally grow on terminal branches of the mycelium; sometimes they are sessile or nearly so, or they may be intercalated in the mycelium itself. An oogonium is illustrated, enlarged 400 diameters, at A, Fig. 33. The oosphere, filled with granular protoplasm or vital formative material, is seen within. Other organs borne on the mycelium are male,

and termed, in reference to their nature, *antheridia*, or organs answering to the anthers of flowering plants. In the course of growth the antheridium comes in contact with the oogonium as at B, and projects a fine beak through its wall, till it pierces the oosphere within as at C. This is the act of fertilisation answering to the discharge of pollen on to the stigma in flowering plants.

In the same way as an ovule becomes a seed after

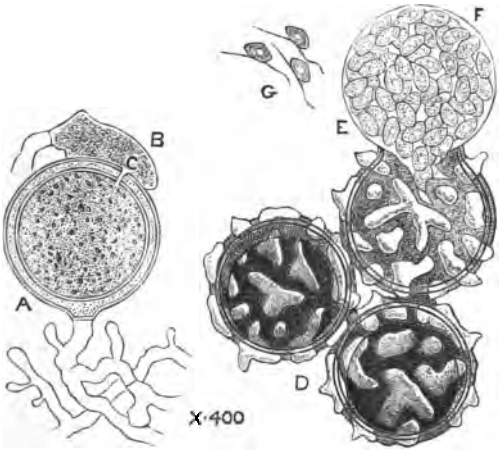


Fig. 33.—White Rust of Cabbages.
Oogonium with Antheridium and Resting-spores, or Oospores of *Cystopus candidus*, Lev. Enlarged 400 diameters.

fertilisation in flowering plants, the *oosphere* becomes an *oospore* or egglike spore, after the contact of the antheridium with the oosphere. The now fertile oospore within the oogonium grows and matures itself whilst still within the supporting leaf or stem for many months, generally for the greater part of a year, and it does not become perfectly ripe till the host plant has decayed. Although the

cabbage leaf which carried the *Cystopus* may be dead and putrid, or reduced to tinder by drought and frost, the oospores or resting-spores remain alive and uninjured, in a dormant state. They change in colour and form, from almost colourless smooth spheres to amber-coloured, warted, globular bodies, as illustrated at D. They are best seen in the putrid remains of plants which have been destroyed by the white-rust fungus. In good material the amber-coloured oospores will be seen closely packed together in the decayed leaf or stem in enormous numbers. The best plan for obtaining resting-spores is to collect leaves infested with white rust and allow them to decay upon a garden bed; after the diseased leaves have perished the oospores will be found during the winter or the following spring in the decayed fragments of foliage.

The oospores germinate on the ground during wet weather in the spring; but the germination may be easily observed in water under the microscope. After a few ripe resting-spores have been placed in a drop of water they will speedily burst, either at once, or in a day or two, according to the state of their maturity. They germinate by bursting, as illustrated at Fig. 33, E; a transparent inner membrane is protruded, and the contained protoplasm, which at first is differentiated into numerous polyhedric portions, at length resolves itself into a large number of oval zoospores as at F. Soon the transparent investing membrane is ruptured, and the zoospores sail out as at G, thus repeating, after from six to ten months' rest, the phenomenon described as belonging to the chains of conidia illustrated in Fig. 32. The zoospores produced by the conidia are precisely the same in size and habit with those produced by the oospores; in both instances they germinate in the same manner after swimming about for three or four hours in water. The difference in size of the zoospores shown in Fig. 32 and Fig. 33 is owing to the fact of the former being enlarged 1000 diameters, whilst the latter illustration is only enlarged 400 diameters.

Cruciferous plants in the spring owe their infection with white rust to the zoospores germinating upon the seed-leaves. No one, of course, has seen such extremely minute objects as zoospores with the unaided eye, so no one has ever seen them naturally transferred from the germinating oospores on the wet ground, to the young seed-leaves of cabbages, cauliflowers, and other cruciferous plants. It is said that the zoospores cannot effectually germinate and form mycelium upon and in leaves and stems of cruciferous plants unless the latter are very young. But as cruciferous weeds infected with *Cystopus* are extremely common, the oospores must occur in profusion in all districts every spring. No doubt the little motile zoospores are carried through moist air by currents of wind, and distributed in every direction throughout the country.

Alternation of crops must tend to diminish white rust. Cabbages, cauliflowers, etc., should not be grown for two years in succession where white rust has prevailed. Cruciferous weeds should be gathered together and burnt, especially when they exhibit the well-known white sprinkling of the white-rust fungus. No cabbage, cauliflower, turnip, or mangel refuse should be allowed to remain in a decaying state throughout the winter in the fields, for in those positions not only the white-rust fungus, but the putrefactive mildew of the cabbage tribe and the fungus of club-root hibernate. Clean and intelligent farming will greatly reduce the attacks of these two, as well as of many other pests.

CHAPTER XVII.

CLUB-ROOT OF TURNIPS, CABBAGES, MANGELS, AND ALLIED PLANTS.

Plasmodiophora Brassicæ, Wor.

THE disease of turnips, cabbages, and allied plants, known in some districts by the popular name of club-root, is recognised in other places as anbury and finger and toe. On the continent the disease is popularly known as hernia or rupture.

Until the last six or seven years no one knew the cause of club-root, but in 1876, after three years' constant attention, M. Woronin, a Russian botanist, as completely explained the nature of club-root in turnip and cabbages, as the Rev. M. J. Berkeley expounded the nature of the murrain of potatoes in 1846.

The observations made by M. Woronin, which have several times been confirmed by others as well as ourselves, seem to place the fact beyond all doubt that clubbing is caused by a fungus named, by M. Woronin, *Plasmodiophora Brassicæ*. *Plasmodiophora* means a bearer or carrier of a plasmodium, and a plasmodium is an Amœba-like mass of protoplasm or vital formative material of changeable form; *Brassicæ*, of course, means that the fungus is peculiar to the turnip and cabbage class. The family to which the fungus belongs is a remarkable one, and is known as the *Myxomycetes* or family of slime-fungi. These fungi have appeared so animal-like to some observers that, by a misinterpretation of analogies, an attempt has been made to transfer them to the Protozoic division of the animal kingdom. With the same idea in view they have been

termed by Professor A. De Bary *Mycetozoa*, or fungus-like animals. No fungologists of repute, however, and very few zoologists, hold either of these views at the present day. When Professor De Bary termed these fungi *Mycetozoa*, little or nothing had been learned of the production of zoospores in fungi, a phenomenon now so well known in *Cystopus*, *Peronospora*, and other genera.

The *Myxomycetes* are especially remarkable in the fact that they do not form cells, cellwalls, tissues, or mycelium, during the period of vegetation, but their protoplasm remains during that time free, and collected into small masses of various and changeable forms. At a certain definite advanced period of growth the vital material of a *Myxomycete* breaks up into small portions, and these portions at length surround themselves with a cellwall, and become either fruits, sporangia, or spores, and in this condition the fungus remains at rest during a certain definite period. If the spores are kept dry they will retain their vitality for several years. After a period of hibernation the sporangia sometimes coalesce, and the spores germinate by the cellwall cracking, and the vital material exuding as a small round or irregularly-shaped mass; this exuded mass speedily becomes furnished with one or two highly-attenuated tails, vibrating hairs, or *cilia*, and with the aid of these tails the little exuded masses are enabled to creep about over any moist surface in an Amœba-like fashion. The exuded masses are capable of multiplication by division, or (generally after a few days) they will unite with each other, and so form a homogeneous mass of protoplasm of larger size, which mass also possesses an Amœba-like movement. This homogeneous mass of combined Amœba-like material ejected from the spores is termed a *plasmodium*. The plasmodium is now capable not only of coalescing with other neighbouring plasmodia, but also of absorbing other Amœba-like spore contents. A plasmodium possesses the power of creeping about by extending armlike processes from its margin,

and by the vital material from the mass repeatedly pressing into the arms or processes. The plasmodium is enclosed by a dense hyaline layer, and this in turn is surrounded by a thin coat of mucilage, which mucilage is sometimes left behind by the progressing plasmodium like a trail of slime from a slug. Although our fields are at all times saturated and traversed by the spore contents or plasmodia of this destructive fungus, yet *Plasmodiophora* has not hitherto appeared in our printed lists or handbooks.

The structure and habits of the members of the whole family of the *Myxomycetes*, with its numerous genera, are too involved and different from each other for any further general description in this place.

Clubbing commonly commences at an early period in the life of the seedling turnip, cabbage, or other cruciferous plant. If we take a young seedling turnip,—one which shows by its flagging foliage and dwindled growth that it is out of health,—and examine the root, we shall probably see it, if attacked by the club-root fungus, something like the illustration at Fig. 34, which is engraved one-half the natural size. The example illustrated represents a seedling turnip two months old. The rootlets will be seen to be swollen with spindle-shaped swellings, generally with a smooth and flowing outline; and this peculiar smooth spindle form of the clubs distinguishes true clubbing from all abrupt tuberous swellings and excrescences, sometimes natural, at other times abnormal, as when caused by the insects and larvæ so common on cruciferous plants. Every swelling in true club-root is not necessarily perfectly smooth or truly fusiform or spindle-shaped, but in the majority of instances, and especially in an early state of growth, this distinguishing mark holds good and is characteristic. Some entomologists have ascribed the origin of club-root to the attacks of Aphides; but Mr. G. B. Buckton, F.R.S., in his "Monograph of the British Aphides," published by the Ray Society, rejects this idea, but thinks some clubbing may

be due to insect punctures on the tap-root when the plant is young. But excrescences caused by insect punctures are quite distinct from true clubbing. Curtis, in his *Farm Insects*, has rejected the idea of Aphides being the cause of clubbing.

To see the nature of the fungus of club-root, one of the smaller spindle-shaped swellings must be cut in two, as on the line A, B, Fig. 34, and from one of the exposed

FIG. 34.—CLUB-ROOT DISEASE OF TURNIPS, ETC.
Root of young Turnip with Clubs.
One-half natural size.

surfaces a thin slice must be cut. If this is done in July, and the slice is viewed as an opaque object and magnified 10 diameters, it will be seen, as in Fig. 35, faintly and curiously mottled and clouded. If an extremely thin atom is now cut off and viewed as a transparent object with a power of 200 diameters, it will be seen as at Fig. 36. The cause of the mottling will now be seen to be due to the presence of a yellowish stringy slime or plasma,

FIG. 35.—CLUB-ROOT DISEASE OF TURNIPS.
Section through a small Club. Enlarged 10 diameters.

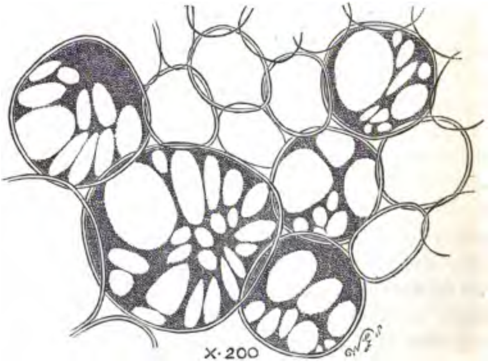


FIG. 36.—CLUB-ROOT DISEASE OF TURNIPS.
Section through Cells of Turnip-root, showing the Plasma of *Plasmodiophora Brassicæ*, Wor. Enlarged 200 diameters.

sometimes wholly filling certain cells, in other instances appearing as strings of slimy protoplasm drawn across from one side to the other. No true mycelial tubes can be seen, and none of the familiar cells so common in most fungi. One fact will strike the observer at once, and that is, the affected cells will be noticed as much larger in size than the ordinary cells of the rootlet—in many instances enormously larger. This distention of the cells is a common result of the attacks of parasitic fungi on leaves and roots, and one can understand at once that if each constituent cell of the infant turnip-root or rootlet is distended to ten or one hundred times its normal size, a clublike growth must result. It will be noted too that the cells, though enormously distended, have not burst.

If a club is examined later in the season—say in October—a very different appearance is presented, and the change we then see has been gradually going on during the autumn months. The protoplasm of the summer has, by the late autumn, broken up into innumerable minute spherical portions, and the stringy, slimy mycelium has been replaced by millions of excessively minute spherical spores. These spores may now be distinctly seen to possess a cell wall. The cells of the turnip are now, even more distended than before, and in many instances they will be seen closely packed with the greatest regularity by vast cohorts of the *Plasmodiophora* spores. It will still be seen that most of the distended cells of the turnip remain intact, and only a few are ruptured. A little pressure of the covering glass of the microscopic slide will, however, speedily break some of the cell walls, and the spores will pour in enormous quantities through the breach into the surrounding film of water. This condition of the disease is illustrated at Fig. 37, enlarged 200 diameters, where the spores are seen pouring out through the breaches in the cell walls. The spores are farther enlarged to 1000 diameters at Fig. 38, so that their size may be compared with other spores drawn to

the same scale in the other illustrations given in this work.

The three larger spherical brown bodies seen in Fig. 37, and the single example in Fig. 38, are resting-spores of the putrefactive fungus of cabbages and turnips, named *Peronospora parasitica*, Pers., and sometimes seen in great

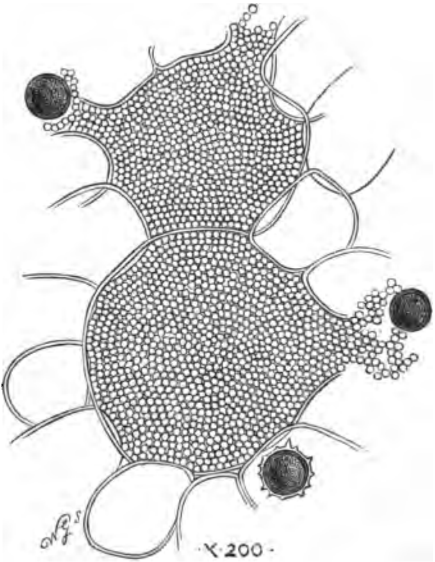


FIG. 37.—CLUB-ROOT DISEASE OF TURNIPS.
Spores of *Plasmodiophora Brassicæ*, Wor., seen within the Cells of Turnip-root. Enlarged 200 diameters.

abundance in turnip plants reduced to putridity by the combined attacks of the *Peronospora* and the *Plasmodiophora*. These larger bodies are the second species of *Artotrogus* (not *A. hydnosporus*) of Montagne.

The *Plasmodiophora* spores remain uninjured and in a

resting state in affected turnips all through the winter; and in the spring, if another transparent slice is taken from a small club formed during the previous year, the

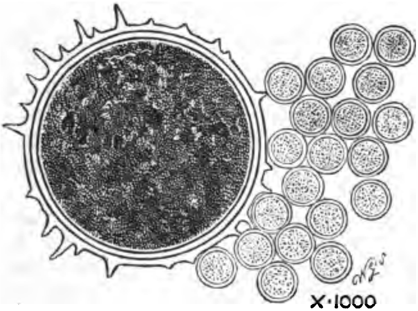


FIG. 38.—CLUB-ROOT DISEASE OF TURNIPS.
Small spores of *Plasmodiophora Brassicæ*, Wor., and single Resting-spore of *Peronospora parasitica*, Pers. Enlarged 1000 diameters.

spores will be found perfectly ripe and ready for germination. This germination takes place as illustrated in

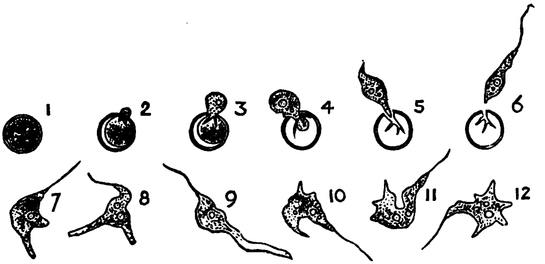


FIG. 39.—CLUB-ROOT DISEASE OF TURNIPS.
Spores of *Plasmodiophora Brassicæ*, Wor., germinating and producing Amœba-like zoospores.

the six spores, enlarged 1000 diameters, and numbered from 1 to 6 on Fig. 39. The cell wall of the spore

cracks, and the contained protoplasm creeps out, as illustrated in the successive figures. First a small protuberance is seen, then a slightly branched arm, next the main growth is attenuated, then the attenuation proceeds to an almost invisible hairlike tail or flagellum; at last the minute speck of protoplasm flies out of the spore wall, often whirling the empty case to some little distance. Each atom of protoplasm which has emerged from the spore is now a free zoospore, or animal-like spore—capable, aided by its hairlike tail, of creeping or sailing along, or whirling round in any film of moisture, as illustrated in the figures numbered from 7 to 12.

These zoospores, like all other zoospores, do not long remain in the zoospore condition. In most fungi zoospores speedily burst and protrude a thread of mycelium; but in *Plasmodiophora* the zoospores quickly coalesce, and when a few have conjoined they form the growth already described as a plasmodium. The viscid plasmodium formed by one set of conjoined zoospores speedily comes in contact with other and similarly-formed plasmodia, and so larger examples are formed. These examples, large and small, are, when in a state of nature, washed out of decaying club-root material into the ground by the spring rains. There, on and in the moist ground, they are able, by pushing out arms and prolongations, and by continually propelling their contained vital material into these extensions, to move about in a sluggish Amœba-like fashion.

All practical agriculturists will now see that when club-root refuse is left in the fields, or thrown on to dung-heaps, and then distributed over the ground, the most certain method is taken for propagating club-root disease, for out of this decayed material innumerable motile plasmodia will be washed into the ground. When the seeds of turnips and cabbages grow and extend their rootlets, the rootlets naturally come into contact with the viscid watery plasmodia in the ground, and these plas-

modia are absorbed into the young turnip plants by the rootlets. It cannot be objected that a plasmodium is too large to find entrance to a plant by the rootlets, for plasmodia are capable of existing in a state of threadlike fineness and watery attenuation beyond conception.

When once in the rootlets, the plasmodia are in the position that best suits them, and in that position they act as true parasites in the host plant, and by their growth excite disease, unnatural distention of the cells, and "club-root."

The proofs that old club-roots, with their contained ripe spores, can really produce "club-root" disease in growing turnips have many times been given of late years, and the experiments have been several times repeated by ourselves. They amount shortly to this. If in spring-time turnip seed is planted in pots in virgin mould, the seedlings will come up unclubbed; but if exactly similar seeds are planted in earth in which old chopped-up clubs have been incorporated, the seedlings will nearly all be at an early period of growth fatally clubbed.

For the prevention of clubbing, an alternation of crops for two or three years may reduce the disease, for, as far as is at present known, *Plasmodiophora Brassicæ*, Wor., is confined to cruciferous plants. As the spores of the fungus can live for more than a year in dry material, more than one season should elapse before turnips or cabbages are again planted in tainted fields. As charlock is often badly clubbed, this, with other worthless cruciferous weeds, should not be allowed, more than is possible, to choke the hedge sides of fields under cultivation with cabbages, turnips, and mangels.

Beyond all other things, it is necessary that old club-root should not be allowed to remain on the ground where turnips or cabbages are to be grown. All the diseased material should be gathered into a heap, and, if possible, burnt.

Prof. Jamieson, in the last annual report of the Sussex Association for the Improvement of Agriculture, advised

farmers not to use manures containing sulphur and chlorine elements; the one given usually as sulphuric acid and sulphate in dissolved or soluble manures, the others given in chloride, or muriate of potash, and in common salt. Sulphuric acid is a characteristic ingredient in nearly all vitriolated or phosphatic manures. Prof. Jamieson states that the only crops which are uninjured by these manures are the cereals, and that they should never be used for other crops unless the soil is unusually black; he considers that club-root and sickness in turnips is aided by sulphur, and that chlorine is injurious both to Swedes and peas. Prof. Jamieson is of opinion that the sulphur in the manure (in whatever form) accelerates the elaboration of the delectable sulphurous material, in which the dormant spore finds abundant sustenance. At the same time, by the readily available form of the mineral food, a flush of premature growth pervades the cultivated plant, and consequent weakness. Simultaneously the fungoid enemy, at the expense of the higher plant, increases in myriads, war is waged, in which the assailing foe—the fungus—is never subdued, but may have either a complete victory in the death of the higher plant, or only partial victory, resulting in a more or less clubbed root, and a more or less normal bulb above.

In August 1883 experiments at Hassocks, in Sussex, a conspicuously unhealthy appearance is said to have been observable in all the turnips of the superphosphated plot; although it had been stated that the club-root disease had previously been unknown in Sussex.

In October the plants were taken up from all the plots, with the following result:—

Manures used.	Total diseased and killed Plants.
Ground coprolite	11.
Ground bone-ash	16.
Superphosphate	51.
No phosphate	45.
Steamed bone-flour	16.
Coprolite and steamed bone-flour	3.

CHAPTER XVIII.

EAR-COCKLE, PURPLES OR PEPPERCORN IN WHEAT, OATS, AND RYE.

Tylenchus tritici, Bast.

For a clear comprehension of the disease of wheat, oats, and rye, named ear-cockle, purples, or peppercorn, it is necessary that the nature of an ear of wheat should be well understood. We will therefore briefly describe the structure of the inflorescence of wheat, so that the peculiarities of ear-cockle may be made clear.

An ear of wheat is technically termed a spike, and the spike consists of a rachis (literally a backbone) or zigzag stem, on which are placed numerous little clusters of grains with their chaffy scales. Each cluster is termed a spikelet, and as a single cluster or spikelet taken from any part of a spike is generally the same in arrangement as all the other clusters on the spike, we will remove one cluster or spikelet for careful observation.

At Fig. 40 is illustrated a spikelet of wheat enlarged two diameters. It will be seen that the whole growth is enclosed between two outer sheaths or bractlike scales, seen at AA; these are termed the two outer glumes—glume merely meaning "chaff." In wheat it is common to see the two outer glumes enclosing five other growths. One of these is an aborted growth seen at B, and the two clusters on each side at C, D, E and F, each include two bractlike scales, one a flowering glume, and the other a pale. Each of the two inner growths encloses a pistil, three stamens, and two minute scales. The lowermost and outer bract of these two is termed the flowering glume;

this has a central mid-rib, and the inner one is termed the pale (meaning also chaff), with two distinct side ribs and no mid rib.

If the parts of a ripe spikelet are compacted together so

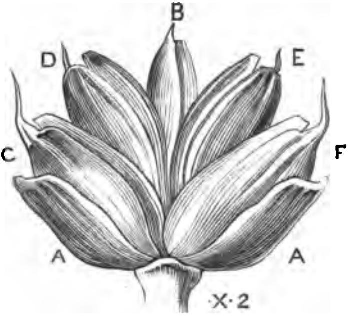


FIG. 40.
Spikelet of Wheat. Twice the size of nature.

that they will not break away under the knife, and a horizontal section is made through all the fruits or grains with their enclosing chaffy scales, the parts of the spikelet will be seen as in the section at Fig. 41, enlarged four

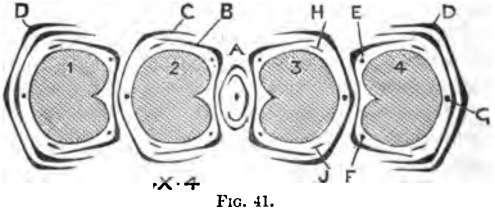


FIG. 41.
Horizontal Section through a Spikelet of Wheat, showing the grains, scales, etc. Enlarged 4 diameters.

diameters. We now see in horizontal section the central abortive growth at A, and the four normal grains, 1, 2, 3, and 4, each enclosed within a pale, with its two side

ribs, as at B, and a flowering glume with its central midrib C. The flowering glume is often capped with a long thread beard or *awn,* familiar in barley and oats. The whole growth is embraced by the two outer glumes at DD.

We will now closely examine one of the four groups, with its two enclosing scales, the flowering glume and pale. Arranged round each pistil (or in the ripe ear—the grain) are three stamens, E, F, and G (Fig. 41), and two beautiful fimbriated transparent, membranous, almost microscopic scales at H, J; the three delicate drooping stamens and two little scales all grow at the base of the pistil, carpel, or grain. The two little transparent scales are usually admitted to represent the perianth of more perfect flowers. The different parts of a grass spikelet possess considerable botanical interest, and the questions are by no means settled as to the exact morphological significance of the glumes, palæ, and scales, and their mode of attachment. The questions are, however, beyond our province here, and need not be discussed in detail. It is remarkable that the two little transparent scales at the base of the pistil are persistent, and in this they differ from the fugitive feathery stigmas and stamens.

As great attention has been directed by botanists to the two minute scales, technically termed *lodicules,* growing at the base of the ovary, and their connection with ear-cockle, a single grain of wheat detached from the spikelet, but still enclosed within its pale, is shown enlarged to five diameters at Fig. 42. The spectator is supposed to be looking towards the interior of the pale, and the furrow or cleft of the seed is away from the spectator and towards the pale. Pendulous from the base of the grain is a withered stamen. On either side of the point of insertion of the stamen, and at the base of the grain, the two minute lodicules are seen at A and B. The wrinkled part of the base of the grain at C is the spot whence the plumule and radicle of the young wheat-

plant will emerge on the germination of the seed. A single scale or lodicule is enlarged to fifty diameters at Fig. 43 to clearly show its form. In text-books these scales are usually described as fringed at the top, but in nature they are also usually fringed down both sides; and a similar fringe belongs to both glume and pale towards

FIG. 42.—Grain of Wheat enclosed in its Pale. Enlarged 5 diameters.

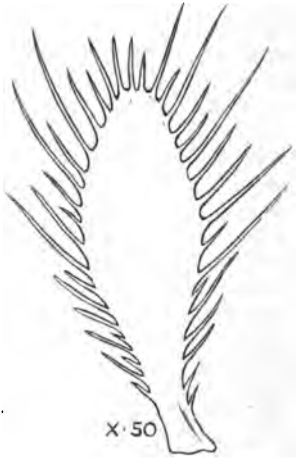


FIG 43. Lodicule from base of Wheat grain. Enlarged 50 diameters.

their base, and a not dissimilar one to the grain at its apex.

We will now leave the normal healthy spikelet, and examine a diseased one. When a wheat plant is affected with ear-cockle, the spikelets present a much thinner, looser, and more open appearance than the healthy ones. This appearance is shown at Fig. 44, enlarged two diameters; here the large normal grains are replaced by four small peppercorns, shown solid black in the illustration.

The small purplish-black grain-like growths found within the flowering glume and pales in the disease known as ear-cockle, are galls caused by the attack of a nematoid or thread-worm, named, by Dr. H. C. Bastian, *Tylenchus tritici*. *Tylenchus* is a compound word derived from the Greek, and indicates the knoblike growth of the galls and the so-called "spear" of the Nematode—that is, the muscular bag forming the back part of the mouth; *tritici*, of course, refers to the classical name of the wheat plant. The popular names ear-cockle, purples, and peppercorn have reference to the form, size, and colour of the little galls; these galls are roughly comparable, on a small

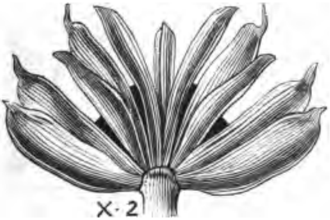


FIG. 44.
Spikelet of Wheat, the grains replaced by the galls of Ear-Cockle. Twice the size of nature.

scale, with the familiar galls found on the leaves of the oak and other plants. The Nematode itself is a close ally of the well-known "eels" of stale paste and vinegar.

In a Nematode-infested wheat spikelet, such as the one illustrated at Fig. 44, the little blackish galls or peppercorns can generally be seen as illustrated between the ill-grown glumes and pales. Four of these galls are shown free at Fig. 45, A, B, C, and D, enlarged five diameters. These galls are commonly two bodies conjoined, seldom a single body, and in rare instances three conjoined bodies, always within the pale and flowering glume. For the reason that the galls are commonly two conjoined bodies

these growths have been associated by Mr. William Carruthers, F.R.S., in the *Journal of the Royal Agricultural Society*, vol. xviii., 1882, with the two minute transparent scales or lodicules belonging to the base of the pistil. In some instances these galls are, however, single growths, with one or more furrows, and the example illustrated at D shows the two persistent lodicules present at its base, proving that the two lodicules which form the perianth of the flower are not invariably the organs which are replaced by the galls. As this particular gall-growth at D is a double one, it probably represents two of the three stamens. A gall of one cell

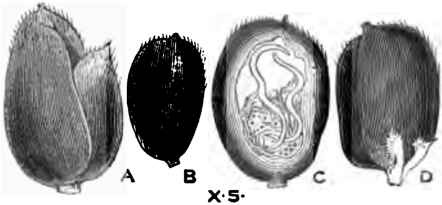


FIG. 45.
Galls of Ear-Cockle from a Wheat spikelet.
Enlarged 5 diameters.

represents the pistil, and galls with three cells represent the three stamens. When a single example of pepper-corn only is produced within the glume and pale, it agrees well with the single central oblong carpel, with its downy top. This view confirms Devaine's observation that the gall is formed from any of the growths belonging to the central part of the flower. On one occasion Devaine detected a gall growing from one of the leaves of a wheat plant.

The galls originate at a very early period of the development of the flowers of wheat, at a time when the different parts which are to compose the flower are repre-

sented by mere minute swellings on the little lateral axis destined to produce the spikelet.

The small worm, we suppose, attacks these swellings—either the one belonging to the pistil, the three belonging to the stamens, or the two belonging to the scales. The parts attacked may, however, belong in part to more than one series,—as one scale and one stamen, or the pistil and one scale, etc. When the puncture is made, an unusual flow of sap to the injured place—possibly a natural attempt to repair the injury—is the result, an extremely common phenomenon in plant injuries. This flow of sap causes the first cells of the monstrous gall-growth to appear: the abnormal growth is rapid in development, and in a short time the assailing Nematode or Nematodes are enclosed within an abnormally-grown cell wall. A section of a mature gall is shown at Fig. 45, C, and a section farther enlarged to forty diameters is shown at Fig. 46, illustrating part of the wall and part of the enclosed colony of Nematodes. Both sections show the comparatively thick nature of the wall of the gall, and the large number of thick obscurely hexagonal cells of which it is built up. It is remarkable that the fungus of corn mildew and other fungi peculiar to corn have been seen growing upon these galls. The fact probably shows how completely the substance of the galls agrees in nature with the substance of the wheat plant from which they are derived.

When a young gall is cut in two and its interior examined, it is found filled with a cottony mass, which, on enlargement with the microscope, becomes revealed as a mass of semi-transparent nematoid worms of all sizes, from mature individuals one-seventh of an inch long, through semi-mature and infant individuals, to transparent eggs, in which the little Nematodes may be seen coiled up. A group of these worms, in all stages of growth, may be seen at A, Fig. 46, drawn to the same scale, *i.e.* enlarged forty diameters, as the adjoining wall of the gall at B. By the time the gall is quite mature the mother worms

have died, and the eggs have burst and produced young.

In vol. xxv. of the *Transactions of the Linnean Society* Dr. H. C. Bastian has described several other species of Nematode found on and in wheat, oats, and other grasses. Dr. Bastian specially adverts to the tenacity of life belonging to the species found under the genus *Tylenchus*, and he attributes this vital tenacity in part to the structure of the integument of the animals. This integument is of such a nature that it enables the Nematodes to resist

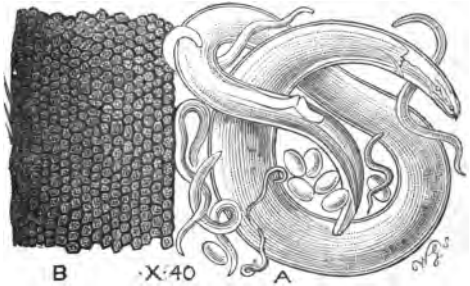


FIG. 46.
Fragment of the wall of an Ear-Cockle gall, with part of a colony of Nematoid worms, *Tylenchus tritici*, Bast. Enlarged 40 diameters.

dessication, and prevents the evaporation of moisture through their tissues. Whilst some Nematodes immediately shrivel up when immersed in gelatine, Dr. Bastian has found that members of the genus *Tylenchus* will move about in gelatine from fifteen to twenty minutes. The power of remaining in a dormant deathlike state for a long series of years Dr. Bastian attributes to some inherent peculiarities of the animals' tissues beyond the reach of detection by optical instruments of even the highest power. The same author say it is an established fact that *Tylenchus tritici*, Bast., is capable of

resuming activity after remaining dormant for twenty-seven years.

Various observers have artificially infected wheat with the *Tylenchus* by placing the living Nematodes taken from a gall in the furrow or cleft of the grain, and then planting the infected seeds in the soil in the usual manner. Or galls may be planted in close contiguity with healthy grain; after a brief time the Nematodes will work their way through the wall of the softened and decaying galls, and come naturally in contact with the young leaves sprouting from the healthy seed. The Nematodes then insert themselves between the sheaths of the leaves, gradually working their way round till they come to the innermost, where they remain till the rudiments of the future ear begin to form. Several grasses, in addition to wheat, oats, and rye, are assailed by Nematodes, notably *Festuca elatior*, L., maize, and different species of bent grass, *Agrostis*.

Other Nematodes attack cucumbers, melons, carnations, and many different plants belonging to our greenhouses and flower and kitchen-gardens. These have never been scientifically described by zoologists, or even named. Sometimes the Nematodes attack the roots, especially the rootlets, and they cause little nutlike swellings to appear. Sometimes the stem, and in other instances the leaves, are made the point of attack, and the Nematodes cause dead pallid patches to appear. On cutting a slice from a pallid spot, or a slice from a nodule belonging to a rootlet, the Nematodes and their eggs are almost invariably met with. The worms are coiled in various ways within the eggs, and after a definite period the eggs burst, and the young thread-worms emerge.

As it has been clearly proved that ear-cockle can be produced by planting the galls containing the Nematodes with sound grain, the greatest care should be taken in separating the galls from the seed-wheat. This should be a very easy matter, as the galls are black in colour, whilst the grain is yellow, and the galls are only one-half

the size of the grains of wheat, making the process of sifting an easy one. Of course all galls should be carefully gathered together and burnt, for under any circumstances such growths and their contents are unpleasant objects to be ground with corn as food. As the little animals inside the galls can live, under favourable circumstances, in a deathlike state for more than a quarter of a century, galls should never be stored with corn or planted.

CHAPTER XIX.

CLOVER DODDER.

Cuscuta Trifolii, Bab.

CLOVER DODDER is such a familiar, and, as some observers say, increasing pest in our fields, that any detailed description of its superficial appearance and habits is unnecessary. Clover dodder is probably perfectly familiar to every observant person who has walked through clover fields.

All the dodders,—and there are some forty or fifty species—belong to one genus of parasitic plants termed *Cuscuta*, a name said to be derived from *Chassuth*, the Arabic name for dodder plants. The *Kadytas* of Theophrastus and the *Cassytas* of Pliny are believed to be dodder. These names, as well as the Arabic name, signify to hold fast, to stitch, and to oppress. The popular name, dodder, is an English form of the Dutch and German names *Dodern*, *Touteren*, and *Todern*. *Dodd* signifies a bunch, and *dot*, a tangled thread. *Trifolii* indicates that the plant now under description invades clovers. The dodders are commonly termed scald-weeds, hell-weeds, or strangle-weeds, and in some districts devil's-guts; the popular names indicate the strong hatred rustics bear towards these weeds.

Cuscutas are closely allied to the Convolvuli of our gardens, and some botanists place them in the same natural order with the convolvulus; others relegate them to a natural order by themselves, named *Cuscuteæ*.

Part of a plant of *Cuscuta Trifolii*, Bab., growing parasitically on clover, is shown at Fig. 47, twice the size of

nature. Most of the characters of the parasite that are visible to the unaided eye are given in this sketch.

Dodders are plants with yellowish or reddish leafless threadlike stems, the leaves being represented by a few small transparent scales. The small, usually pinkish, bell-shaped, sometimes sweet-scented flowers, as in clover dodder, are collected in little closely-packed heads or

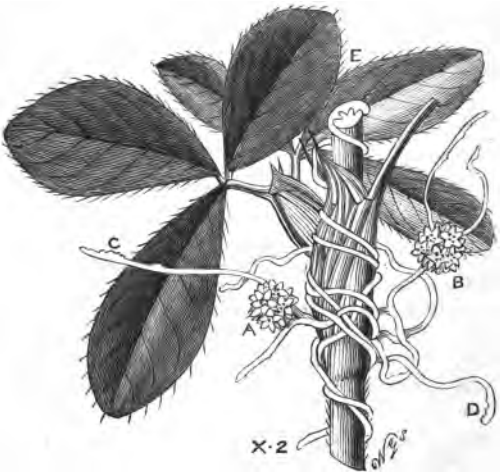


FIG. 47.—CLOVER DODDER.
Cuscuta Trifolii, Bab., growing on Clover.
Twice the size of nature.

clusters, as shown at A, B, Fig. 47. Each floral perianth is usually divided into four or five segments. The flowers are commonly succeeded (but not in the case of clover dodder in this country) by four small seeds. The threadlike stems are furnished with numerous very small suckers, as at C, D, with which the parasite attaches itself to its host.

Dodders grow in all hot and temperate regions, and

they fix upon a great variety of plants in addition to field clovers and lucerne. The best known of these host plants are flax, thyme, broom, heath, furze, cabbages, nettles, hops, cranberry, rock-rose, centaury, scabious grass, bracken, yellow-rattle, eyebright, bastard toad-flax, yellow bedstraw, camomile, sow thistles, tomatoes, and even the vine.

It is extremely common to find seeds of dodder amongst impure clover seeds imported from the Continent. In some instances it is easy to sift dodder away from the larger-seeded varieties of clover, and we know that most seed-merchants are very particular in this respect. In other instances the dodder and clover seeds approach each other so nearly in size that sifting one from the other is impossible, and the No. 17 sifter becomes quite useless.

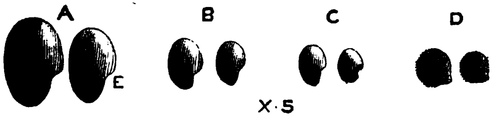


FIG. 48.
Seeds of Red Clover, Yellow Trefoil, Dutch Clover, and Clover Dodder. Enlarged 5 diameters.

For the purpose of comparison, two seeds of perennial red clover are illustrated at Fig. 48, A; at B the seeds of yellow trefoil; at C of white Dutch clover; and at D the seeds of clover dodder, all to the same scale, viz. five times the size of nature. All clovers in cultivation vary in size between the limits shown by A and C in Fig. 48. The examples for measurement were kindly forwarded by Messrs. Sharpe and Co. of Sleaford, Messrs. Sutton and Sons of Reading, and Messrs. Edward Webb and Sons of Wordsley, Stourbridge. The dodder seeds were sifted out of impure foreign importations. In a pound of average clover there are 250,000 seeds.

A dodder seed is brown, dull, and minutely granular outside when seen with the aid of a strong lens, whereas

clover seed, although often brown, is smooth and shining, with a minute scar or protuberance at one point of the circumference at E, Fig. 48. At this point the radicle, the first or elementary root of the plant, emerges at the time of germination. This scar is almost invisible in dodder seeds. When seen in section a clover seed materially differs from a dodder seed. The interior of the clover seed shows the presence of cotyledons or seed-leaves, as at Fig. 49, A, enlarged ten diameters; and the first rudimentary rootlet or radicle at B. The illustration at C shows a clover seed after it has been planted for three days or a week in moist sand. The testa, or outer integument of the seed, has burst, and the first

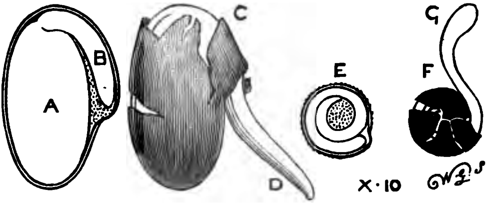


FIG. 49.
Seeds of Perennial Red Clover and Clover Dodder, seen in section, and germinating. Enlarged 10 diameters.

rootlet of the infant clover plant at D is descending to the sand. Clover-dodder seed is engraved to the same scale at E and F; at E the seed is shown in section; there are no seed leaves, but the young plant within consists of a simple thread, spirally coiled round a little central mass of fleshy albumen. At the period of germination the thread emerges with a dilated end as at G, and the granular coat of the seed frequently breaks up as shown. If a germinating seed in this condition is transferred to a slip of glass and held before a strong light, the spiral embryo will be seen through the cracked testa as here illustrated. Sometimes the cotyledons or seed

leaves are represented by one or two very minute scales in germinating dodder.

Clover and dodder seeds, farther advanced in growth, are shown at Fig. 50, twice the size of nature. The clover seeds on the left are sending their first roots deep into the earth, whereas the dodder seeds on the right are sending their threads into the air in search of a host on which to live parasitically. The ground line is indicated at A. Clover and dodder seeds generally germinate after the lapse of a week or less ; but certain seeds of clover dodder from the

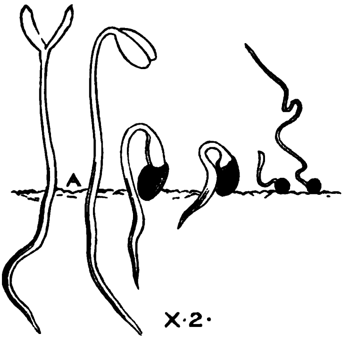


FIG. 50.
Clover and Dodder seeds germinating.
Twice the size of nature.

sample we experimented with did not germinate till two months had passed. The variation in the time of rest in and on the ground before germination is an obvious advantage to the dodder, for, if the first dodder seedlings find no hosts ready for them, other seedling dodders, during a period of two months, still have a good chance. Clover often remains without producing other than the two first seed leaves for one or two weeks, and during that period the young dodders often attach themselves to the clover seedlings, as illustrated at Fig. 51, enlarged ten diameters.

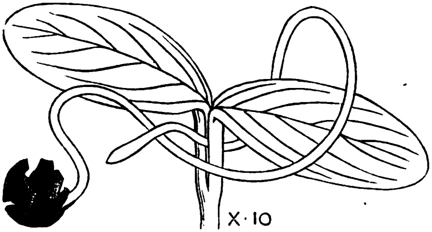


FIG. 51
Germinating Dodder seed, with its threadlike stem fixing on the seed leaves or Cotyledons of Clover seedling.
Enlarged 10 diameters.

FIG. 52.
Infant Dodder plant on a young Clover leaf.
Enlarged 10 diameters.

For the same period the dodder threads, as a rule, have produced no suckers, although in one or two erratic examples we have seen suckers whilst the embryo thread was still within the burst testa. Dodders bear minute transparent scales on their threads as equivalents to leaves, but we have not seen them in clover dodder till the young plants have been several weeks old. When dodder twines round a young seedling clover, the rapidly-growing clover carries the dodder away from the ground, the old withered testa being sometimes still attached to the dodder thread for a week or two. A dodder plant a few weeks old, on a young clover leaf, is shown enlarged ten diameters in Fig. 52. As the clover grows the dodder now grows with it, and the parasite is lifted higher and higher from the ground. As the spring and summer advance, the dodder flowers profusely, and as the clover plants grow in size and come in contact with each other, the dodder spreads from one host to another. The dodder, in growing, repeatedly branches and rebranches, and throws out long arms, so that during a single summer one or two infested clover plants will help to spread the dodder over a large area. The parasite cannot live on the remains of the plants it has destroyed, so, in the process of growth, it leaves the central clover plant for other plants at the circumference of a dead circle of clover, which may be many feet or even yards in diameter.

At Fig. 53 is shown a fragment of clover stem cut from the top of the stem at E, as illustrated at Fig. 47. This illustration is enlarged fifteen diameters to show the connection by suckers of the twining dodder with the stem of the clover. On examination with the microscope it is seen that not only has the dodder no roots or true leaves, but it is destitute of green colouring matter, the substance which helps to elaborate the food of plants, and which occurs so abundantly in clover. Dodder has none of the small mouths or organs of transpiration so frequently adverted to in these notes, but its

outer cells, seen at A, on the contrary, are somewhat like the pallisade cells found on the upper surface of ordinary leaves. In the centre of the dodder threads there is a woody cylinder, as at B, surrounded by colourless, somewhat loose, cellular tissue, C. The suckers, D, proceed from

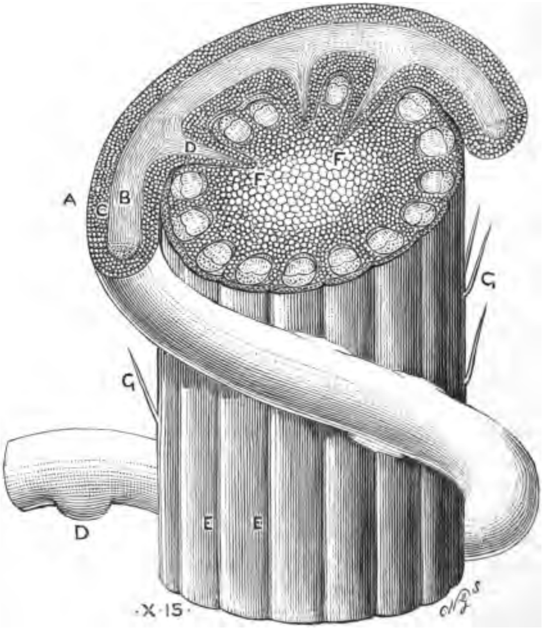


FIG. 53.
Fragment of Clover stem with Dodder entwined to show the connection by the suckers of Dodder. Enlarged 15 diameters.

the central woody portion of the threadlike stem, and are surrounded by a wall of colourless cells. The suckers of *Cuscuta Trifolii*, Bab., are pushed into the fine longitudinal furrows EE (which are always present in clover stems),

until they reach the central pith FF, as illustrated. The suckers could not penetrate the clover stem were it not for the woody skeleton belonging to each sucker; this atom of hard pointed woody material pierces the stem like a small thorn. Hairs of the clover stem are shown at GG. The connection of a sucker of dodder with the clover stem, as seen under the microscope, is illustrated, farther enlarged to fifty diameters, in Fig. 54. The outer pallisade-like cells of the dodder are shown at AA, AA. The woody cylinder at BBB, the loose cellular tissue at CCC, and the point of a sucker, inserted in a clover stem, at D. The centre of the clover stem is shown by the pith-cells at E, the cells of the clover bark at FF, and two fibro-vascular bundles at GG. The parasitic life of clover dodder commences with the insertion of the first sucker into the host plant. When the pith is reached by the suckers pushing themselves in between the cells of the stem of the host, the cellular tissue of the dodder comes into close contact with the living cells of the clover, and the result is, the vital juices elaborated by the clover pass through the cell walls of the clover into the cells of the dodder, and so the sap of the clover feeds the parasite by transfusion. The dodder grows with such extraordinary rapidity when it has once fixed on clover, and it produces so many branches and brachlets, with such a vast number of suckers, that the growth of the parasite generally far exceeds that of the host. The consequence is, the dodder completely drains out the elaborated juices of the clover and kills it by exhaustion. The destruction of the clover is also hastened by the great weight of the accumulated masses of entangled dodder; for one commonly sees the clover quite prostrate on the ground, whilst most of the thickly-matted dodder growth is on the top. The profuse growth of dodder in some clover fields was well illustrated by a correspondent of the *Agricultural Gazette*, who wrote on 9th July 1870, p. 941, that his men had found

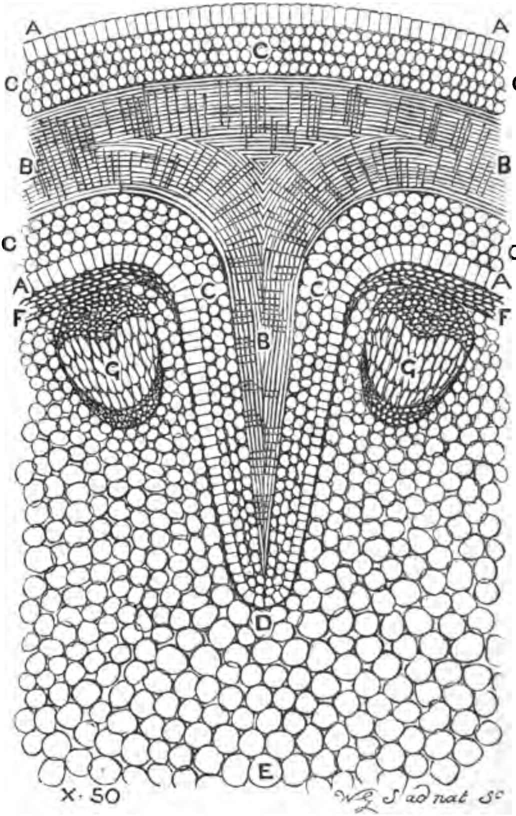


FIG. 54.
The anatomical connection of Clover Dodder with a Clover stem.
Enlarged 50 diameters.

several patches in the fields near Bridport, from two to three yards square. The labourers, for a joke, clothed

themselves with the matted threads of the parasite, and went home as if clothed in bear skins. Clover dodder is generally said to be an annual; but observers are not wanting who have expressed a belief that it is often perennial, and lives on from year to year irrespective of the introduction of new seed, which, indeed, it very seldom produces in Britain. The dodders are said to be acrid and purgative, and mischievous to flocks and herds. It is singular that the parasite should be capable of elaborating acrid principles from the juices of a sweet non-acrid host.

Dodders are still largely imported to Britain in unclean foreign seed. Prof. Lindley has stated that both clover dodder and flax dodder were first imported to this country from Afghanistan so lately as 1843. Dodder is so common now that Prof. Buckman, to whom we are indebted for a most interesting and instructive essay on dodders, records an instance of seventy bushels of flax dodder seeds being sifted out of a single field of flax seed, whilst a year or two afterwards almost as much was separated from a crop of flax grown at the Royal Agricultural College.

On rare occasions clover dodder produces seeds in Britain; and as there is evidence that the threadlike stems are sometimes perennial, dodder refuse should never be left on the ground to rot. Every patch of dodder should be carefully raked together and burnt, and by this process and careful sifting its appearance in the fields can generally be prevented. Some agriculturists, on first seeing the yellow patches in the clover fields, remove all the clover from the outer edges of the invaded patch for a width of about eighteen inches; this leaves nothing for the dodder to prey upon, as the threadlike stems cannot stretch across the eighteen inches of vacant ground. The clover is removed because it is extremely difficult to entirely remove dodder.

CHAPTER XX.

GRASS MILDEW.

Erysiphe graminis, D.C.

There are few fungi more common or injurious in warm dry weather than the fungus of grass mildew, grass blight, or wheat rust,—or white rust, as it is termed in America, named *Erysiphe graminis*, D.C. It is possible that the familiar straw blight of agriculturists, already described, may be caused by the mycelium of the *Erysiphe*, and this is an additional reason for directing special attention to grass mildew or blight. The generic name *Erysiphe* was the term given to mildew by the Greeks; the specific name *graminis* needs no explanation. The fine, creeping, jointed mycelium of *Erysiphe graminis*, D.C., forms a white superficial mildew on the living stems and leaves of cereals and other grasses in the summer and autumn. When the white mildew patches are examined in the autumn with a very strong lens, they will be seen sprinkled with minute black dots, as illustrated twice the natural size on the wheat stem in Fig. 55. The spawn of this mildew is generally supposed to be incapable of penetrating the tissues of plants; but suckers have been described as belonging to the mycelia of some allied species of mildew. With these minute suckers the *Erysiphe* adheres to its host, if the suckers do not indeed pierce the leaf cells and derive nourishment therefrom, after the manner of *Peronospora*. In the summer the mycelium gives rise to vast numbers of vertical moniliform, or necklace-like groups or chains of conidia or spores, as illustrated at Fig. 56, enlarged 400 diameters. This peculiar

fruit of the mycelium was at one time considered a perfect fungus, and was described under the name of *Oidium monilioides*, Lk. The meaning of *Oidium* has been already explained, and *monilioides* means necklace-like, and refers to the growth of the fungus, which resembles a string of beads.

FIG. 55.—GRASS MILDEW. Wheat Stem invaded by *Erysiphe graminis*, D.C. Twice the natural size.

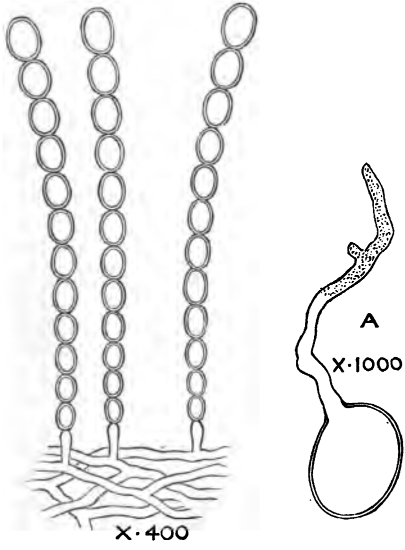


FIG. 56. *Oidium monilioides*, Lk. The early condition of *Erysiphe graminis*, D.C., enlarged 400 diameters. Germinating conidium enlarged 1000 diameters.

The *Oidium* is extremely common on the *Gramineæ* in the summer, and it may always be found on grass, and especially rankly growing grass in damp positions. The necklace-like growth of the beadlike conidia is so delicate that the slightest touch or breath destroys their chainlike arrange-

ment. If, however, infected grass is kept in damp air, a fragment of a leaf may generally be successfully cut, examined without water with a low power of the microscope, and the *Oidium* seen in a growing condition. When thus examined the profuse chainlike growth may be easily observed. If placed under a cover glass for examination under the higher powers of the microscope, the beadlike spores or conidia instantly break away from each other, so inconceivably slight is their attachment. The moniliform habit can, therefore, only be seen with a low power applied to the dry living fungus whilst *in situ*. In water or damp air the conidia, and especially the topmost conidium, quickly germinate and produce thin threads, as illustrated at Fig. 56, A, enlarged 1000 diameters. This constant spore production and germination is incessantly continued through the summer months, till at last a thick grayish-white coat of mildew more or less covers all infected plants. The conidia are so small that it would take about a million to cover a square inch. The *Oidium* state of grass blight may be compared with the *Oidium* of the turnip, illustrated to the same scale at Figs. 27 and 28. The grass *Oidium* is somewhat taller, but the spores of the turnip *Oidium* are more than twice the length of those of our present plant. *Oidium monilioides*, Lk., is a typical plant. The *Oidium* growth of the fungus, however, and the production of the profuse mycelium is only a preparatory stage of growth for the perfect *Erysiphe* which generally follows; it has been observed that when the *Oidium* does not appear till late in the summer, the *Erysiphe* or perfect condition is never produced, and the whole growth of the fungus is confined to the *Oidium* stage. Under favourable conditions of growth, the *Oidium* threads of the summer produce in the autumn little brown globose bodies termed conceptacles. This condition of the mildew is shown on the wheat stem in Fig. 55. When examined even with a powerful lens, these little blackish dots, termed conceptacles, appear less in size than fine grains of dust;

but when magnified with a moderately high power of the microscope, they appear as spherical bodies, furnished with a large number of slender, curved, radiating, tentacle-like arms or branches, the whole growth being partly buried in the spawn, as illustrated in Fig. 57, enlarged 100 diameters. The limit of the page will not admit of a higher magnification than 100 diameters; it must there-

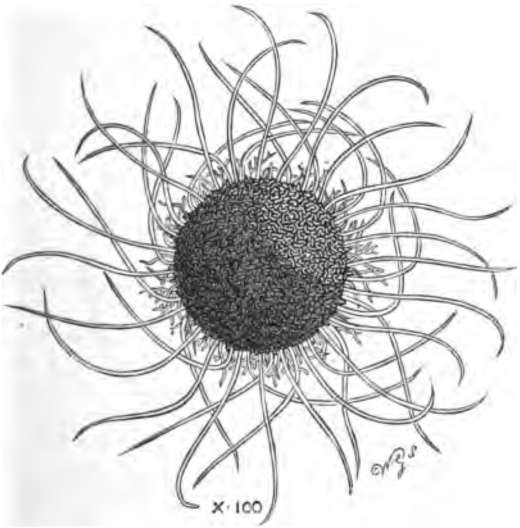


Fig. 57.
Conceptacle of *Erysiphe graminis*, D.C.
Enlarged 100 diameters.

fore be borne in mind that this *Erysiphe* is a comparatively large fungus when placed side by side with others which are magnified 200 and 400 diameters. The difference in size between this *Erysiphe* and *Peronospora exigua*, W.Sm., illustrated, enlarged 400 diameters, in Fig. 2, is very striking.

The term conceptacle explains itself; it simply means a receptacle formed of one valve. Sometimes these bodies are termed *perithecia*, or boxes enclosing the bladders, termed *asci* or *thecæ*. These bladders always in turn enclose spores or sporidia. The conceptacles arise, it has been said, at a point where two specialised threads of spawn cross each other, and where the enlarged ends of two spawn or mycelium tubes come in contact in a manner similar, it has been said, with the contact of the anther with its pollen with the stigma in flowering plants.

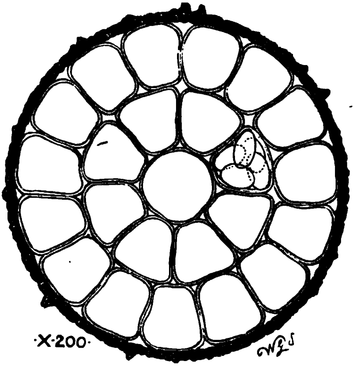


FIG. 58.
Horizontal section through a Conceptacle of *Erysiphe graminis*, D.C.
Enlarged 200 diameters.

The conceptacle or perithecium, after it is once formed on the mycelium, quickly grows in size, and speedily acquires a brown or blackish tint. The wall of which it is composed is built up of minute, firm, closely-compacted cells, resembling externally, on a very small scale, the irregular pattern so frequently seen belonging to the epidermis of many leaves, as of the pea. Towards the base of the perithecium certain privileged cells throw out curved unbranched processes or tentacle-like filaments of

different sizes, some very small, and others comparatively long. The largest of the mature perithecia are, however, so small that it would require more than 100,000 to cover a square inch. To understand the structure of these minute perithecia and their contents it is necessary to cut them in two both horizontally and vertically. Two sections of this nature are shown at Figs. 58 and 59, enlarged 200 and 100 diameters. By referring to the horizontal section, enlarged 200 diameters, at Fig. 58, it will be seen that twenty-four closely-packed transparent bladders have been cut across ; whilst in the vertical section, enlarged 100 diameters, at Fig. 59, five of the

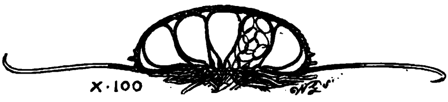


FIG. 59.
Vertical section through a Conceptacle of *Erysiphe graminis*, D.C
Enlarged 100 diameters

central bladders have been cut through vertically. With a little careful manipulation these contained bladders or asci may be squeezed out of the perithecium, and then, upon the application of a higher power of the microscope, it will be seen that each bladder contains eight spores, technically termed sporidia. A single bladder or ascus, with its spores *in situ*, is shown both in Figs. 58 and 59. Three of these asci, farther enlarged to 500 diameters, are illustrated at Fig. 60. One ascus containing the normal eight sporidia *in situ* is shown at A, whilst the figure at B shows the sporidia emerging from the top of the ruptured ascus. The transparent asci are so small that it would take $2\frac{1}{2}$ millions of them, containing 21 millions of sporidia, to cover a square inch. The peculiar shape of the oval sporidia, slightly flattened in their longest dimensions like the egg of a tortoise, is worthy of note. One of these bodies is shown, enlarged

1000 diameters, in the act of germination at C. The asci and sporidia of *Peziza postuma* (B. and Wils.), illustrated to the same scale in Fig. 9, may be referred to for comparison of size and form.

The autumn-borne perithecia do not burst and set free their contained sporidia during the autumn in which they have been formed, but they fall to the ground with the decaying grasses on which they have lived during the summer. They rest on the ground during the winter,

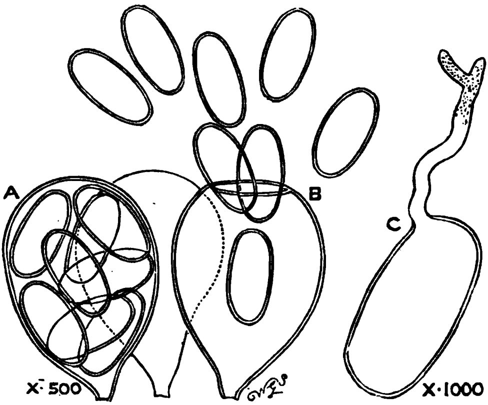


FIG. 60.
Asci and Sporidia of *Erysiphe graminis*, D.C., enlarged 500 diameters. Germinating Sporidium, enlarged 1000 diameters.

and the hard wall of the perithecium effectively protects the contained asci, and the asci in turn protect the tender sporidia against all ordinary frost, dryness, or damp. No sign of life can be detected in the fallen perithecia till the following spring or early summer, and then, if old decaying grass or straw is searched over, the perfectly uninjured perithecia may be found. In the early summer these bodies burst on the ground, as illustrated at Fig. 61,

enlarged 100 diameters. When they burst the contained bladders or asci often burst at the same time, and the living sporidia, after their six months' rest, fly into the air. At other times the bladders or asci themselves fly out of the perithecia, and sail, each with its little load of eight sporidia, through the air. When in the air the asci or bladders burst, and the spores are set free in the atmosphere. The facts just given can easily be seen when old grass or straw infected with *Erysiphe* is kept in damp air

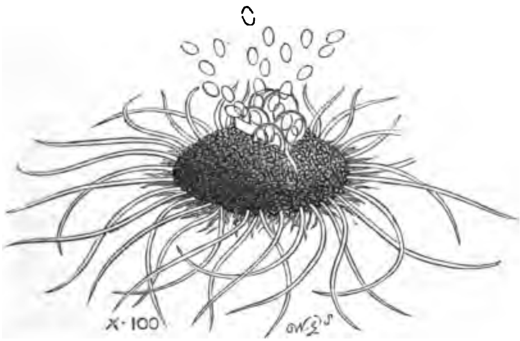


FIG. 61.
Conceptacle of *Erysiphe graminis*, D.C., bursting in spring.
Enlarged 100 diameters.

under a bell-glass, if strips of glass smeared with glycerine are suspended over the infected leaves. On to these strips of glass the asci and sporidia will be ejected from the perithecia. It is a curious fact that the little sporidia are so ready for germination in the spring that they commonly burst and produce spawn threads as they sail about in the air.

Such of the sporidia as alight on the Gramineæ or grasses attach themselves to their hosts by their spawn threads, and speedily produce a necklace-like *Oidium*

similar with the one which preceded their own *Erysiphe* condition.

Dr. H. W. Harkness has described, before the Microscopical Society of San Francisco, *pycnidia* upon the spawn of this fungus as found in California. *Pycnidia* are small conceptacles containing stylospores, or spores after the nature of conidia. The "white rust," as it has been termed in America, first appeared in California in 1877 on mature wheat. In that year it covered half a million acres of wheat, destroying some of the crops. We have taken pains to completely illustrate this common, curious, and destructive fungus, for, as far as we know, no complete illustrations have hitherto been given. Léveillé's illustration, generally referred to, in the *Ann. des. Sc. Nat.*, vol. xv., 1851, t. 10, f. 33, is very bad. It shows the appendages branched and the asci without sporidia ; the scale of magnification is also omitted.

Hops, peas, beans, roses, and many other plants, are preyed upon by fungi very closely allied to the fungus of grass blight.

Grass blight is synonymous with bad, impoverished grass, with mildewed hay, and ill-nourished herds and flocks. The life of the fungus which causes the blight is preserved through the winter in decaying mildewed grass and straw. These facts therefore teach us that all mildewed material should, as far as possible, be gathered together in the late autumn or winter and destroyed. If all the autumn-borne perithecia are destroyed it is obvious there can be no *Oidium* in the spring. The destruction of all infected material is perhaps impossible, but all the facts known in reference to the fungus of this disease point to the great desirability of clean farming, and to the necessity of destroying as much mildewed grass and straw refuse as possible. If all farmers would agree to one course of action the bad effects of diseases like the one here described would be greatly lessened.

CHAPTER XXI.

CORN MILDEW—SPRING RUST AND MILDEW.

Puccinia Rubigo-vera, D.C.

The disease of wheat, popularly known under the name of corn mildew, is the best known and most widely-spread of all plant diseases. Agriculturalists are familiar with the reddish spots of "rust" early in the season, and, later on, the black spots of autumn and winter termed "mildew." These spots are different conditions of the same parasitic fungus, the "rusts" being early conditions of the "mildews." Many observers believe that rusts and mildews have a third condition of growth, and that the mildews of wheat are capable of jumping over an apparent gap and causing a blight of comfrey, bugloss, alkanet, or barberry; and the blights of these plants, termed *Æcidia*, in turn being capable of causing new "rusts," and ultimately "mildew" of corn.

The subject of the mildews of corn may be approached from several points; and as farmers first become acquainted with the pests every year in the spring, when the stems and leaves of their cereals become rusted, we will start with the familiar rust of spring, premising that botanists term the rust *Uredo*, and the mildew *Puccinia*. These terms have been already explained.

There are two rusts of corn—one termed *Uredo Rubigo-vera*, D.C., the other *Uredo linearis*, Pers. Both are followed by a *Puccinia*, the first by *P. Rubigo-vera*, D.C., and the second by *P. graminis*, Pers. The first, *Uredo*, with its *Puccinia*, is less known and less generally injurious than the last; but as it appears first in the season

and sometimes entails great losses, it may be more convenient to describe it first.

The spring rust of wheat appears in March, April, and May, on grasses and cereals: it is common on soft grass, *Holcus lanatus*, L.; creeping soft grass, *H. mollis*, L.; barren Brome grass, *Bromus sterilis*, L.; and wall barley, *Hordeum murinum*, L. Its specific name,—*Rubigo-vera*, means "true rust."

If a leaf of wheat invaded by "true rust" be taken in the month of April or May and examined with a strong lens, it will be seen, as on Fig. 62, enlarged three diameters.

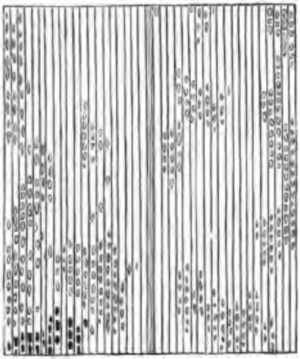


FIG. 62.—Fragment of Wheat leaf invaded by *Uredo Rubigo-vera* D.C. Enlarged 3 diameters.

The minute livid yellow pustules are the sori of the *Uredo;* in the bottom left-hand corner of the illustration a few black spots will be seen,—these are the advanced or *Puccinia* condition of the parasite. If we place a fragment of the leaf under a low power of the microscope and magnify twenty-five diameters, we shall see the pustules as at Fig. 63. It is now evident that the fungus within the plant has, in reaching maturity, burst the epidermis of the wheat leaf. The fungus may be seen as a fine yellowish or orange powder, which is set free by the slightest touch and carried away in the air by the faintest breath. If we now make a transverse section through a very small pustule, cut off a transparent slice from the exposed surface, and magnify 200 diameters, we shall see the interior of the pustule as at Fig. 64. This is engraved to the

same scale as *Puccinia mixta*, Fl., Fig. 13, which may be referred to for comparison. The yellow powder is now seen as a mass of yellowish sub-spherical or ovoid spores, each spore filled with dense granular protoplasm, is supported on a short stalk and springs from an involved stratum of mycelium. A single spore is seen emerging through the centre of a ruptured pustule at A. The transparent circles at BB are part of the cellular tissue of the wheat leaf. When the spores escape in this matter, as they do in inconceivable numbers, many fall on to the leaves from which they have grown. In their new position they germinate, as at Fig. 65, by the protrusion of a spawn-thread from both sides, the vital material pours from the spore

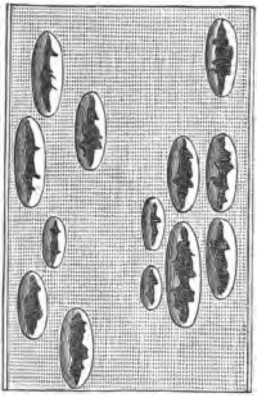


FIG. 63.—Pustules or Sori of *Uredo Rubigo-vera*, D.C., on Wheat leaf. Enlarged 25 diameters.

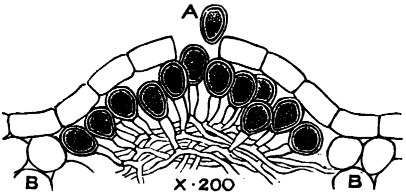


FIG. 64.
Transverse Section through a pustule or Sorus of *Uredo Rubigo-vera*, D.C. Enlarged 200 diameters.

into the threads ; and as the spores get empty a septum appears as at A, and cuts off the connection of the germ-tube with the spore. The germinal threads now enter

the organs of transpiration of the leaf, and there form a new stratum of mycelium, from which new *Uredo* pustules arise. Under favourable circumstances this growth and

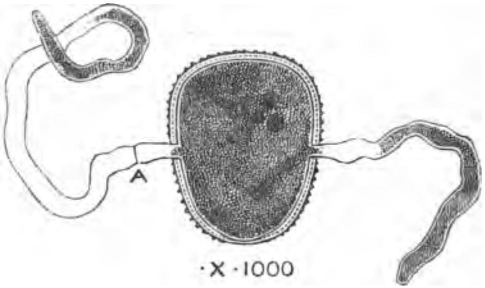


FIG. 65.
Germinating spore of *Uredo Rubigo-vera*, D.C.
Enlarged 1000 diameters.

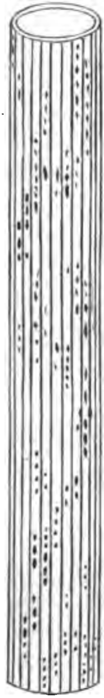
regrowth of successive crops of spores goes on for several weeks, until the whole plant, whether wheat, rye, or some wild grass, is at length permeated by the spawn.

The above-described condition of spring rust is the same with *Uredo Rubigo*, D.C., *Uredo Rubigo-vera*, Lév., *Cæoma Rubigo*, Lk., *Trichobasis Rubigo-vera*, Lév., and *Trichobasis glumarum*, Lév.

As the autumn and winter approach, the pallid and yellowish spots of the *Uredo* vanish, and black spots appear, and this black condition is the mature fungus of the mildew named *Puccinia Rubigo-vera*, D.C. A small piece of wheat-stem is illustrated, enlarged five diameters, at Fig. 66, the small black dots show the *Puccinia* pustules. Reference may be here made to Fig. 12, where similar pustules are shown, to the same scale, on a fragment of a flower stem or scape of chives. The black sori are farther enlarged to twenty-five diameters at Fig. 67, to show that the pustules are almost identical in appearance with the *Uredo sori* of Fig. 63; the only difference

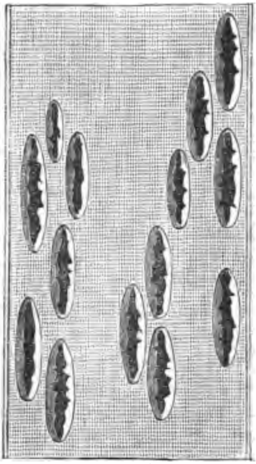
is the *Uredo* produces simple oval yellow spores; whilst the *Puccinia* produces dark brown or blackish spores, each of the latter having a joint or septum across its narrowest diameter.

A section through a *Puccinia* sorus is shown, enlarged 200 diameters, at Fig. 68; the *Puccinia* spores are pushing in the same manner as the *Uredo* through the ruptured epidermis of the wheat leaf. The dark elongated bodies at AA are said to be *paraphyses*—possibly in this case undeveloped



X·5

FIG. 66.—Fragment of Wheat stem invaded by *Puccinia Rubigo-vera*, D.C. Enlarged 5 diameters.



·X·25·

FIG. 67.—Pustules or Sori of *Puccinia Rubigo-vera*, D.C. Enlarged 25 diameters.

Puccinia spores. The compound spores of *Puccinia Rubigo-vera*, D.C., act as resting-spores, for although

developed in the autumn, they will not, as a rule, germinate till the following spring; they then burst in the manner illustrated at Fig. 69, enlarged 1000 diameters, upon old decaying grass and straw upon the ground. In the warm damp weather of April and May one or both segments of a teleutospore will burst and produce a transparent thread of mycelium, termed by botanists pro-mycelium, because it is the first mycelium of a cycle of phenomena belonging to *Puccinia.* The compound teleutospore is shown at AA, with its short stalk B still attached. As the pro-mycelial threads, CC,

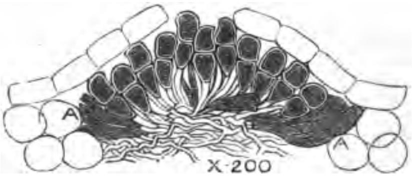


Fig. 68.
Transverse section through a pustule or Sorus of *Puccinia Rubigo-vera*, D.C. Enlarged 200 diameters.

increase in length, the protoplasm pours from the spores into the tubes. A series of septa then appear, two of which are seen at DD, and these septa enclose the protoplasm in the growing end of the tube; from this end two or three minute transparent or pale yellowish spores, termed pro-mycelium spores, as at EEE, are borne: these speedily fall from their slender supports, and germinate very readily on damp surfaces, as shown at F.

It might be considered reasonable to suppose that these little pro-mycelium spores, as produced in the spring, would, if placed on the leaves of grasses, reproduce the *Uredo* first described; but many botanists believe it to be proved that they do not and cannot at once reproduce the *Uredo;* but when placed on the leaves of certain plants

belonging to the Borage family, as *Lycopsis arvensis*, L., *Anchusa officinalis*, L., *Symphytum tuberosum*, L., etc., they produce an apparently totally different fungus,

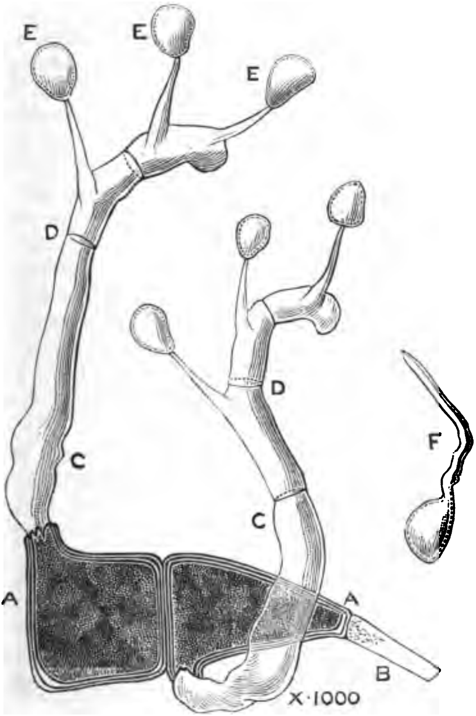


FIG. 69.
Teleutospore of *Puccinia Rubigo-vera*, D.C., germinating in spring. Enlarged 1000 diameters.

termed *Æcidium asperifolii*, Pers. When the *Æcidium* in due course produces its spores it is said that the

Æcidium spores give rise to the *Uredo* if placed on certain grass leaves. In the next chapter will be found a description and illustration of the *Æcidium.*

Before dismissing *Puccinia Rubigo-vera,* D.C., we may say that *Uredo* and *Puccinia* spores often, though not in this species, grow together in the same pustules, and that *P. Rubigo-vera,* D.C., and *P. graminis,* Pers., often grow in company on the same leaves and stems. These parasites divert the material which should go to the production of good ears of grain for their own support; they therefore cause the general growth of corn to be weak and the ears to be small in proportion to the virulence of the attack: the straw, too, is not only damaged, but is made the means of carrying the disease over the winter for the following season. A variety of *P. Rubigo-vera,* D.C., termed *P. simplex,* Kör., also occurs. The teleutospores in this plant consist chiefly of a single cell, similar to the single-celled examples of *P. mixta,* Fl., illustrated in the left-hand spore in Fig. 14. *P. simplex,* Kör., has also been described as a species under the name of *P. Hordei,* Fl., and *P. anomala,* Rost.

Puccinia Rubigo-vera, D.C., occurs in Europe on *Calamagrostis Epigejos,* Roth.; *Arrhenatherum elatior,* L.; *Holcus mollis,* L.; *H. lanatus,* L.; *Avena flavescens,* L.; *Festuca elatior,* L.; *Serrafalcus secalinus,* Bab.; *Bromus mollis,* L.; *Secale cereale,* Walld.; *B. arvensis,* L.; *B. asper,* L.; *Triticum vulgare,* Vill.; *Lolium temulentum,* L.; *Hordeum vulgare,* L.; *H. distichum,* L.; *H. murinum,* L.; and *H. secalinum,* Trin.

Suggestions for preventing and destroying the mildews of corn are adverted to in the chapter where the evidence for the connection of *Puccinia* and *Æcidium* is reviewed.

Puccinia Rubigo-vera, D.C., is the same with *P. straminis,* Fl., and *P. striæformis,* West.

CHAPTER XXII.

BORAGE BLIGHT.

Æcidium asperifolii, Pers.

As the disease of barberries, believed by many botanists to be one condition of the fungus of summer rust and mildew of wheat, is popularly known as "barberry blight," it may be well to term the closely allied fungus of the Borage family, which is similarly associated by many with the spring mildew of corn, borage blight.

The name of the fungus blight found on various plants belonging to the Borage family, and considered by many observers to be one form of the spring rust of corn, is *Æcidium asperifolii*, Pers. The name *Æcidium* is derived from the Greek, and should properly be written *Œcidium;* the word means a little chamber, in reference to the form of the fungus in an infant state, as shown at C in our illustration of the *Æcidium* of summer mildew of corn, Fig. 83;—*asperifolii*, refers to the nature of the coarse hairy leaves of several of the Boraginaceous plants on which the *Æcidium* grows.

The fungus of spring rust and mildew, already described, is generally common in Britain,—so common that persons walking through wheat fields have sometimes had their boots and clothes covered with the orange spores. The *Æcidium*, on the other hand, said to be one condition of the *Uredo* and *Puccinia*, is one of the rarest of British plants. *Æcidia* grow within the tissues of plants, and in these positions they form minute spherical balls, filled with chains of whitish or yellowish, semi-transparent, generally spherical, spores. In the process of growth the immersed

spheres burst through the cuticle of the host plant—generally from the under side of the leaves, and often through the stem. As the *Æcidium* cups mature they burst at the exposed apex, and the fractured part turns back so as to give the little fungus growths the form of minute cups filled with spores.

The under side of a leaf of Tuberous Comfrey, *Symphytum tuberosum*, L., is illustrated, natural size, at Fig. 70. Two groups of the cups belonging to *Æcidium*

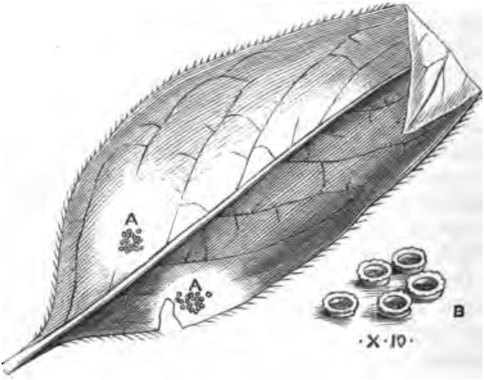


FIG. 70.
Leaf of Tuberous Comfrey, *Symphytum tuberosum*, L., invaded by *Æcidium asperifolii*, Pers., natural size.
***Æcidium* cups at B enlarged 10 diameters.**

asperifolii, Pers., are shown at AA. Each cluster of cups is surrounded by a large pallid disease patch, which has been caused by the exhaustion of the vital material of the leaf by the spawn of the fungus which at first grew within. The fungus growth has also caused the leaf to become torn. Five of the little *Æcidium* cups are shown, enlarged to ten diameters, at B.

At A, Fig. 71, one of the mature *Æcdium* cups is farther enlarged to fifty diameters ; the cup has burst, and

its frayed edges, made up of transparent polyhedral cells, are outwardly curved. Springing from the interior are the chains of globose (or slightly polyhedral) spores. The cells of the wall of the cup and the contained spores are nearly the same in size, the spores being somewhat larger than the cells; the difference in the appearance of the two under the microscope is very striking, for the component cells of the cup have a thin wall, and are filled with a watery fluid, whereas the spores have two or even three coats, and are filled with granular and lustrous protoplasm. The spores, unlike the constituent cells of the *Æcidium*, are commonly studded with minute

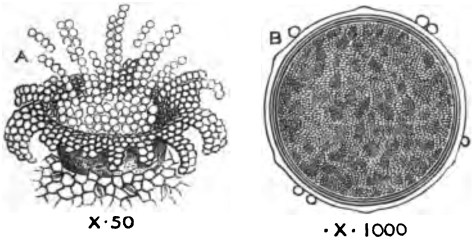


FIG. 71.
Æcidium asperifolii, Pers. Single cup enlarged 50 diameters; Spore enlarged 1000 diameters.

sub-globose particles as at B, enlarged 1000 diameters; these small bodies, as seen attached to the circumference of the spore, are considered to have the same function as pollen-grains, and are termed *spermatia.*

As the nature of *Æcidium* is fully explained under *Æcidium Berberidis*, Pers., Chap. XXIV., it is not necessary to describe it in this place, especially as *A. asperifolii*, Pers., is not a completely typical species.

It is sufficient here to say that Professor A. de Bary of Strasbourg states that the spores of this *Æcidium* will not reproduce an *Æcidium* on germination, but, on the

contrary, will produce *Uredo Rubigo-vera*, D.C., if placed on the leaves of various grasses and cereals. Professor de Bary states, *Neue Untersuchungen über Uredineen*, ii. 1866, that the germ tubes of the *Æcidium* spore, on germination, bore into the cuticular cells of certain grasses, and develop a mycelium in the body of the leaf, which mycelium at length gives rise, after about eight days, to *Uredo Rubigo-vera*, D.C.

Æcidium asperifolii, Pers., has been found in Europe on *Cynoglossum officinale*, L.; *Borrago officinalis*, Tour.; *Anchusa officinalis*, L.; *A. arvensis*, Bieb.; *Nonnea pulla*, D.C.; *Symphytum officinale*, L.; *S. tuberosum*, L.; *Cerinthe minor*, L.; *C. alpina*, Kit.; *Echium vulgare*, L.; *Pulmonaria officinalis*, L.; *P. tuberosa*, Schrk.; and *Lithospermum arvense*, L.

CHAPTER XXIII.

CORN MILDEW—SUMMER RUST AND MILDEW.

Puccinia graminis, Pers.

THE summer rust and mildew of corn, as caused by the fungus known as *Puccinia graminis*, Pers., is of greater importance from an economical point than the spring rust and mildew already described. The losses entailed on farmers by attacks from *Puccinia graminis*, Pers., have sometimes reached 50 or even 75 per cent on the whole crop; where there should have been 40 or 50 bushels only 20 have been harvested, and in some instances only 12 have been recorded.

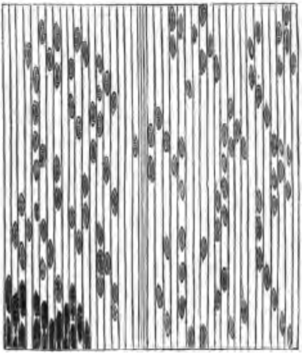
The first parasite may be found in its early or *Uredo* state in March, April, and May, whilst the summer rust is seldom seen till June or July.

As in the last, the early condition of summer mildew is the rust stage, termed in this case *Uredo linearis*, Pers. The generic name has already been explained; *linearis* refers to the elongated form of each dot or disease pustule. The black condition of the fungus, as found in autumn and winter, is the one termed *Puccinia graminis*, Pers. The name *Puccinia* has been explained; *graminis* needs no explanation.

Botanists in former times believed the red and black spots of rust and mildew to be caused by two distinct fungi; it is, however, very common to see both *Uredo* and *Puccinia* spores in the same pustule.

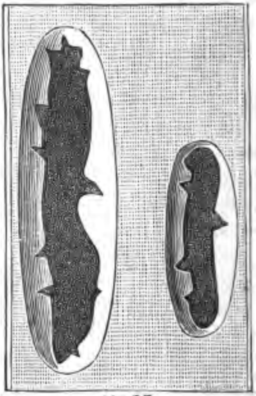
Part of a wheat leaf suffering from summer rust, *Uredo linearis*, Pers., is shown at Fig. 72, enlarged three diameters. The *Puccinia* or mildew is replacing the

Uredo in the black spots in the bottom left-hand corner of the illustration. Two pustules (technically *sori*, or spore cases), are further enlarged to twenty-five diameters in Fig. 73. It will now be instructive to turn to Figs. 62 and 63, where the spring rust is illustrated to the same scale.



·X·3·

FIG. 72.—Fragment of Wheat leaf invaded by *Uredo linearis*, Pers. Enlarged 3 diameters.



·X·25·

FIG. 73.—Pustules or Sori of *Uredo linearis*, Pers. Enlarged 25 diameters.

Neither *Uredo Rubigo-vera*, D.C., or *U. linearis*, Pers., are confined to one side of the foliage of cereals; they grow on both sides, and (especially in *U. linearis*, Pers.) attack the inflorescence with its glumes and pales. The latter organs have been described under ear-cockle.

The *Uredo* of summer rust is less livid or yellow and more orange or brown in colour than the *Uredo* of spring rust, and being altogether larger and more robust in growth it splits and lacerates the cuticle of the affected plant more completely; but the description of the pustules of spring rust apply generally to the larger sori of the rust of summer.

If we now cut across the larger of the two pustules of summer rust, as illustrated at Fig. 73, and magnify a thin transparent slice from the cut surface 200 diameters, as was done with *U. Rubigo-vera*, D.C., we shall see it as at Fig. 74. We now find that a typical pustule of summer rust is so large that the page of our book is insufficient for it. The engraving at Fig. 74 therefore shows one-half the diameter of a sorus only, AB being the centre line. The closely packed *Uredo* spores are supported on somewhat longer pedicles than in *U. Rubigo-vera*, D.C., and the spores themselves differ not only in colour but also

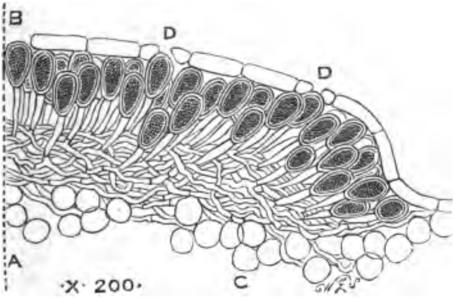


FIG. 74.
Transverse section through half a Pustule or Sorus of *Uredo linearis*, Pers. Enlarged 200 diameters.

somewhat in shape and size. They spring from a stratum of involved jointed brownish mycelium. The constituent cells of the wheat leaf are shown at Fig. 74, C, and two organs of transpiration belonging to the leaf are shown at DD. Two typical *Uredo* spores, supported on their transparent pedicles, are enlarged 1000 diameters in Fig. 75. No individual spore in a sorus exactly agrees in shape and size with another ; they vary, however, within well-defined limits. Germination has commenced in the smaller of the two spores at A.

The *Uredo* spores fall very readily from their support-

ing stems, and as they fall the faintest breath of air wafts them away.

If *Uredo* spores are kept in moist air for a few hours they readily germinate. This germination usually takes place by the protrusion of two germ tubes or threads of mycelium, one from each side, usually near the middle, and rarely from or near the top of the spore. The spots whence the tubes are destined to emerge from the spores

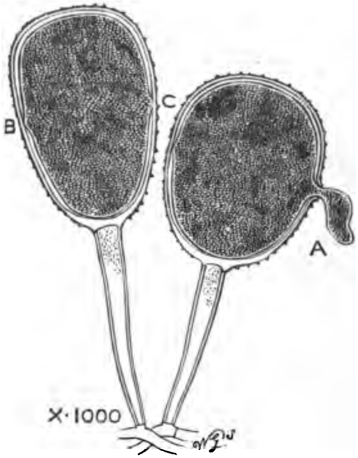


FIG. 75.
Spores of *Uredo linearis*, Pers. Enlarged 1000 diameters.

can often be readily seen before germination takes place as at BC, Fig. 75. These germinal spots are weak places in the inner wall of the spore. Two spores, enlarged 400 diameters, are shown germinating on a fragment of the epidermis of a wheat plant in Fig. 76. These two spores show the extreme limit of size. It seldom happens that both germ tubes continue their growth ; one usually remains effete, as at AA, whilst

the yellowish granular contents of the *Uredo* spore pour into the other and more strongly growing tube, BB, Fig. 76. In a day, or a day and night, this stronger thread will have grown in a convolved fashion, as at C, and will have attained many times the length of the spore from which it started, and the whole of the contents of the spore will now be in the germinal tube. When this stage of growth is attained a septum or stop grows across the mycelial thread, as at D, and the dead and empty spore case is cut off from the living thread.

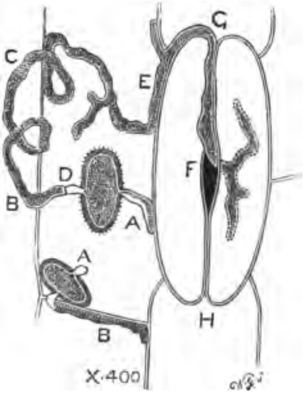


Fig. 76.—Two spores of *Uredo linearis*, Pers., germinating on a fragment of the epidermis of a Wheat leaf. Enlarged 400 diameters.

If this process of germination is watched on glass and not on a cuticle stripped from a wheat leaf, it will be noticed that the germ tube will flow into any little scratch or depression on the glass, just as a brook gradually flows into the lowest positions of a river valley, or as rain water makes its way into our brooks by following little depressions in the land surface.

If, on the other hand, the process of germination is watched on a shred of transparent epidermis torn from a wheat leaf, the thread of mycelium will be observed to follow the minute depressions formed where the constituent cells of the epidermis meet, and by following these fine depressions, as at E, the germ tube at length naturally arrives at one of the minute mouths, organs of transpiration, or *stomata*, belonging to the plant, as at F. These are the lowest points on a leaf surface, and the

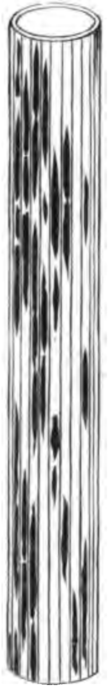
germ tube of the rust fungus enters the tissues of the host plant through these apertures, just in the same way as it would enter a small hole in a microscopic slide or go over the edge of a slip of glass, as we have many times seen it do. A stomate belonging to wheat is very large in comparison with the size of a spore; the length of an organ of transpiration is from G to H.

When once the *Uredo* mycelium has found its way amongst the tissues of the wheat plant, the germ tube is in its natural position; it now branches right and left, and ramifies amongst the green constituent cells of the leaf. The mycelium here quickly produces new *Uredo* pustules, which burst through the wheat cuticle in fresh places, so that a wheat leaf which may have had only a few pustules in June, may have the number more than quadrupled by July by the continued germination of the *Uredo* spores on the leaf surface. No doubt the mycelium also spreads in the leaf from the base of the original pustules.

Before proceeding farther it must be noted that these *Uredo* spores are very short lived, for if they germinate on any unsuitable material they quickly perish. When all the vital material is once poured out of the spore into the germinal tube, growth can proceed no farther on an unsuitable matrix. It is only when the spores germinate on grasses, and the germ tubes find their way through the organs of transpiration into the tissues of the supporting plant, that the *plasma* of the fungus is able to continue its existence. It is therefore obvious that when the frosts of winter arrive and grasses are for the most part dead, or, if alive, sluggish to the last degree, that this fungus, which has a much more slender hold on life than any grass, must perish. Unless the mycelium of the rust fungus has moderate warmth, sufficient moisture, and the interior of a living grass, it probably always collapses and perishes.

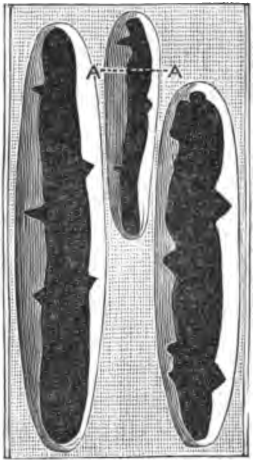
As in the spring rust of wheat, the life of the fungus of summer rust and mildew is carried over the winter in the

following manner: As the summer advances the rust mycelium within the leaf of the wheat plant gradually ceases to produce rust spores, and, instead, produces dark brown or blackish spores—jet black to the unaided eye. A fragment of a wheat stem is illustrated at Fig. 77, enlarged five diameters; the jet black pustules here shown represent the genuine corn mildew of agriculturists, and this perfect condition of the disease is the *Puccinia graminis*, Pers., of botanists. The



X·5

FIG. 77.—Fragment of Wheat stem invaded by *Puccinia graminis*, Pers. Enlarged 5 diameters.



X·25

FIG. 78.—Pustules or Sori of *Puccinia graminis*, Pers. Enlarged 25 diameters.

black disease spots are much larger in *P. graminis*, Pers., than in *P. Rubigo-vera*, D.C., as may be seen by referring to

Fig. 66. Three pustules are farther enlarged to twenty-five diameters in Fig. 78. A reference to Fig. 67, where the pustules of *P. Rubigo-vera*, D.C., are illustrated to the same scale, will show the difference in size of the sori belonging to the two mildews. The familiar condition of the burst epidermis of the leaf is seen in both, and it is noticeable in *P. graminis*, Pers., that in bad cases the black pustules commonly become confluent.

We will now take a transverse section on the line AA., though the smallest of the three pustules illustrated in Fig. 78. If we magnify a thin transparent slice from the

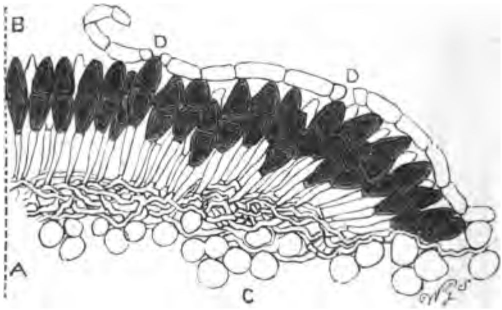


FIG. 79.
Transverse section through half a Pustule or Sorus of *Puccinia graminis*, Pers. Enlarged 200 diameters.

cut surface 200 diameters as before, we find the limits of the page insufficient for it. One-half the section, therefore, only is illustrated in Fig. 79, the centre line being shown at AB. If reference is now made to the section through a complete pustule of *Puccinia Rubigo-vera*, D.C., as illustrated to the same scale in Fig. 68, the difference in size between the two sori will be apparent. The difference in form of the contained teleutospores will be seen when the teleutospores of *Puccinia graminis*, Pers., Fig. 80, are compared with the germinating teleutospore

of *P. Rubigo-vera*, D.C., illustrated in Fig. 69, both enlarged 1000 diameters. The supporting stems of *Puccinia graminis*, Pers., are larger in proportion, and are accompanied by no paraphyses in the sori.

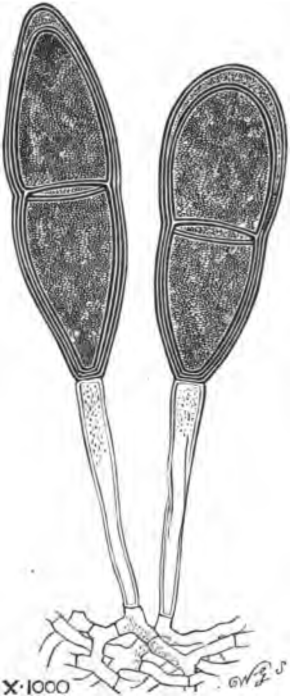


FIG. 80.—Teleutospores of *Puccinia graminis*, Pers., as borne in autumn and winter. Enlarged 1000 diameters.

To see the germination of the black *Puccinia* spores, old *Puccinia* invaded straw must be looked for in the spring months, and the *Puccinia* spores must be taken from a pustule with a small knife or needle, and placed in a film of water under a thin cover glass on a slide, and kept in moist air (to prevent evaporation) under a bell glass. Germination usually takes place, as in *P. Rubigo-vera*, D.C., by the protrusion of a thread from each of the two cells of the *Puccinia* spore, as illustrated at Fig. 81, enlarged 1000 diameters. These two threads, the first produced in the spring, are the pro-mycelium, or the first mycelium, of one end of the cycle springing from the "finishing spores" or teleutospores belonging to the other end. This pro-mycelium is seen at AA. The pro-mycelium proceeds to no great length, but after sometimes attaining three or four times the length of the black

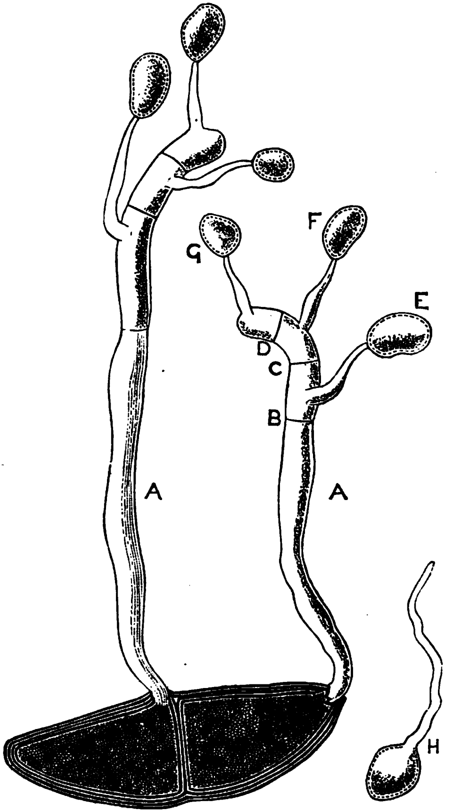


FIG. 81.
Teleutospores of *Puccinia graminis*, Pers., germinating in early summer. Enlarged 1000 diameters.

teleutospore belonging to the *Puccinia*, it usually coils round somewhat like a shepherd's crook, produces about

three stops, joints, or septa, as at B, C, D, and from each of the three separate pieces three fine branches arise, and these branches bear at their tops three irregular oval transparent, very pale amber-coloured spores, as illustrated at E, F, G. These spores are the third of the series. First we have *Uredo*, or rust spores; then *Puccinia*, or black mildew spores; last, spring or *pro-mycelium* spores.

Pro-mycelium spores germinate very readily in a film of water on glass, as illustrated at H, by the protrusion of a fine tube of mycelium.

In a state of nature the black *Puccinia* spores germinate upon straw, as it rots on the ground in the spring, and the minute ovoid pale lemon-coloured spores are carried about in the air in millions—that, too, in the springtime, when corn first becomes invaded, and when the first signs of summer rust or *Uredo* appear upon our cereals.

Judging by what is well known amongst other fungi, it would be perhaps reasonable to suppose that these little hyaline spores (particularly as they arise from specialised resting-spores) would reproduce the *rust* from which they were originally derived (and nothing else), if they came in contact with grasses. Many botanists believe this to be a fact; others say they do not, but, on the contrary, that the cycle of corn mildew is not complete with the production of these spores. Many observers believe that before the pro-mycelium spores can cause the rust of corn they must be nursed by a barberry bush; that the lemon coloured spores invariably refuse to effectually grow on the leaves of grasses, but when placed on the leaves of barberries they find themselves so thoroughly in a natural position that they do not, on germination (like the majority of fungus spores) gently follow the uneven surface of the leaf cells, and so quietly enter by the stomata; but the mycelium from the spores, it is said, sinks into the hard leaves of the barberry, through the cells of the epidermis (not between them) to the body of the leaf, and there,

having gone from a monocotyledonous plant to a dicotyledonous one, another fungus is produced of an apparently totally different character, named *Æcidium Berberidis*, Pers.

This is the fungus of barberry blight, described in the next chapter. Our comments on the possible connection of the barberry fungus with the fungus of summer mildew of corn is discussed farther on.

Puccinia graminis, D.C., has been recorded in Britain upon *Phalaris arundinacea*, L.; *Phleum pratense*, L.; *Alopecurus pratensis*, L.; *A. fulvus*, Sm.; *Agrostis vulgaris*, With.; *A. alba*, L.; *Calamogrostis Epigejos*, Roth.; *Aira cæspitosa*, L.; *Avena sativa*, L.; *A. fatua*, L.; *A. pratensis*, L.; *A. flavescens*, L.; *A. elatior*, L.; *Holcus lanatus*, L.; *Poa annua*, L.; *P. nemoralis*, L.; *P. pratensis*, L.; *Molinia cœrulea*, Mœnch.; *Dactylis glomerata*, L.; *Festuca gigantea*, Vill.; *F. spectabilis*, Jan.; *F. tenella*, Willd.; *Bromus mollis*, L.; *B. tectorum*, L.; *Lolium perenne*, L.; *Triticum vulgare*, Vill.; *T. repens*, L.; *T. caninum*, Huds.; *Elymus arenarius*, L.; *E. glaucifolius*, L.; *Hordeum vulgare*, L.; *H. sylvaticum*, Huds.; *H. murinum*, L.; *H. distichum*, L.; *Ægilops ovata*, L.; *Secale cereale*, Walld.

CHAPTER XXIV.

BARBERRY BLIGHT.

Æcidium Berberidis, Pers.

There is perhaps no family of plants more free from fungi than the *Berberidaceæ*, and in this fact the family greatly differs from the *Gramineæ*, on various members of which the fungi of spring and summer mildew of corn are so prevalent. It is also noteworthy that the *Boraginaceæ*, upon some members of the order, as already described, the supposed second condition of spring mildew of corn—*Æcidium asperifolii*, Pers.,—occurs, are also free from the attacks of fungi to an extraordinary degree. Grasses are all badly infested with fungus parasites and epiphytes. The only important fungus peculiar to the barberry is the one named *Æcidium Berberidis*, Pers. The generic name *Æcidium* has been explained; the specific name *Berberidis* explains itself.

Æcidium Berberidis, Pers., is frequent on the common barberry, *Berberis vulgaris*, L. It also grows rarely on the more ornamental species of *Berberis* and on the *Mahonias* of our gardens.

At Fig. 82 is illustrated, natural size, a few leaves attached to a small fragment of a branch of the common barberry. The parasitic *Æcidium* almost invariably grows on the under surface of the leaves, as there shown, although it may be detected rarely on both sides, and indeed on every part of the plant. The *Æcidium* growths are seen at AAA. The *Æcidium* clusters, of which there are ten in the illustration, are groups of little sulphur-coloured spots embedded in dark red, swollen, or hypertrophied

patches, on the leaves. If we examine the upper surface of the leaves we shall see reddish patches similar with those below, but these upper patches are more or less covered with little black dots technically termed *spermogones*. These spermogones, of which there are four groups in Fig. 82, are illustrated at BBB. Although the spermogones usually grow on the upper surface of the leaf, sometimes they may be seen on the lower surface. They

Fig. 82.
Barberry leaves invaded by *Æcidium Berberidis*, Pers.
Natural size.

sometimes grow on the same patches with the *Æcidium* cups on the lower surface; at other times they appear by themselves without *Æcidia*. As each spermogone dot is smaller than the point of a pin they are easily overlooked, especially when they grow in very small companies, or as single specimens. The spermogones usually appear before the *Æcidium* cups.

If we look at the black dots with a strong lens we shall still, owing to their excessive smallness, only see them as

black dots; but if we look at the *Æcidium* clusters with a similar lens, we shall see companies of beautiful sulphury yellow cups, bursting open through the lower epidermis of the leaf, and each cup filled with yellow powder resembling small pollen-grains.

To understand the nature of the *Æcidium* cups and the black spermogone dots, we must cut a section through the barberry leaf, and this section must be so made that it

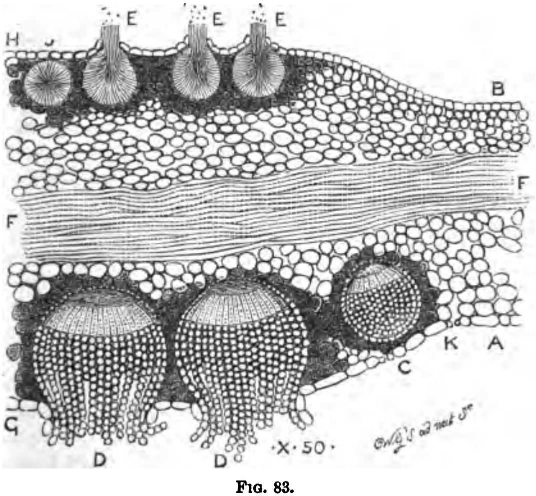


FIG. 83.
Section through a Barberry leaf, showing the cups of *Æcidium Berberidis*, Pers., below, and the Spermogones above. Enlarged 50 diameters.

will pass through the centres of the cups and the spermogones. Such a section is illustrated at Fig. 83, enlarged 50 diameters. A represents the lower surface of the leaf, and B the upper. At C one of the little *Æcidia* is seen buried (a small chamber full of spores) in the tissues of the leaf, and at DD two of the *Æcidium* cups are seen quite mature and open, the epidermis of the barberry leaf

being rent. These cups may be compared with the *Æcidium* cups of the allied *Æ. asperifolii*, Pers., illustrated to the same scale in Fig. 71. At EEE three of the little black spermogones are seen in section. In the middle of the leaf, at FF, amongst the green cells, may be seen a longitudinally cut mass of vascular tissue or spiral vessels belonging to one of the veins. The abnormal thickness of the leaf caused by the presence of the fungus is shown at GH. An embedded unripe spermogonium is shown at J, and an organ of transpiration at K.

From a large number of observations made with the view to trace the origin of the *Æcidium* cups and the spermogonia in the barberry, we believe it takes place in the following manner:—If sections are repeatedly taken through affected barberry leaves it will be seen that numerous minute granules and extremely small disjointed fragments of mycelium may be seen in the intercellular spaces. The fragments and granules vanish by degrees into the finest dust at one end of the series, and appear as short threads at the other and growing end. As the disease advances the granules extend in growth, and appear as fine yellowish-orange tubular mycelial threads furnished with septa. This mycelium has a natural tendency to grow towards both surfaces of the leaf, the growth becoming more profuse as the surfaces are neared. When the mycelium has reached the epidermal cells, under and upper, it forms minute compact knots; the upper knots at length become the spermogonia, and the lower the *Æcidium* cups.

At Fig. 84 is represented a section through an *Æcidium* cup, enlarged 150 diameters. The lower epidermis of the leaf is shown at AB, ruptured by the fungus from within at CD. The fine septate, almost granular, mycelium, from which the fungus springs, is shown at the top of the illustration at D, and creeping amongst the intercellular spaces at E. The outer coat, or *peridium*, of the cup, consisting of a single stratum of transparent polyhedral

investing cells, is shown at FF, and the sulphur-yellow spores hanging in chains from the open cup at G. As the spores composing these chains drop away into the air, others are produced by a continued growth from the bed of fine mycelium or spawn at D. The shading indicates the

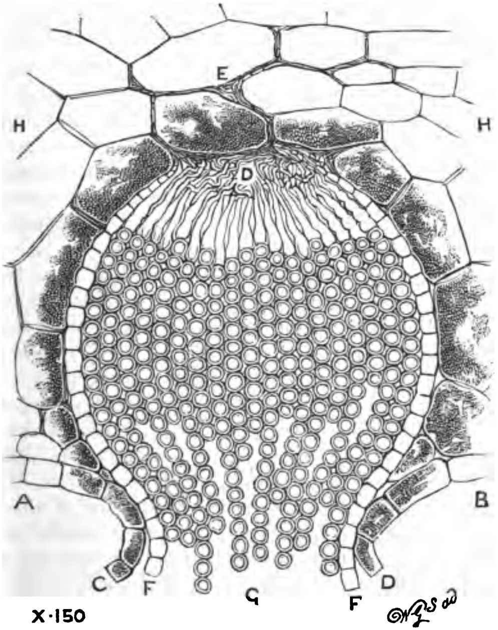


FIG. 84.
Section through a cup of *Æcidium Berberidis*, Pers. Enlarged 150 diameters.

crimson corrosion of the cells of the barberry leaf caused by the presence of the embedded *Æcidium* cup, and the constituent cells of the leaf are shown at HH.

The growth of the spermogonia is not quite the same

with that of the *Æcidium* cups. The mycelium gradually approaches the upper epidermal cells by the intercellular spaces. When it is very near the surface it forms minute knots similar with the knots of the *Æcidium* cups, but the growth differs in an important particular; for whereas the *Æcidium* cup grows from the base, as at D, Fig. 84, the spermogonium grows by a constant protrusion of new threads from the circumference to the centre. A spermogonium, even when almost mature, is like a brownish circular ball, with a loose enclosing mesh of mycelial threads, and from this bark-like mesh innumerable rays of mycelium reach to the centre, the central spot being darker than the rays. The name, spermogonium, means a flask or case containing *spermatia*, and spermatia are extremely minute bodies with a function supposed to be similar with that of pollen.

A ripe spermogonium is illustrated at Fig. 85, enlarged 300 diameters. It must be particularly noted here that this spermogonium is magnified to twice the scale of its accompanying *Æcidium* cup, Fig. 84. This is necessary in order to show the much finer details of all its parts. The first thing to be noticed by the reader is that the constituent cells of the leaf, as at AA, although magnified twice as many times as the similar cells at HH, Fig. 84, are not nearly so large as the latter. The explanation of this is, that the cells belonging to the upper part of the leaf where the spermogonia grow are very much smaller in size and much more closely compacted together than the cells belonging to the lower and looser portion of the leaf.

The upper epidermal cells of a barberry leaf are shown at BC, Fig. 85, and burst apart at DE. The spermogonium has no true wall or bark, but its entire outer surface is a woven coating of extremely attenuated, brownish, sometimes almost granular mycelium; this mycelium can be traced into the adjoining intercellular spaces of the leaf, as at FG. The illustration shows the mycelium belonging to the outer surface of the immersed spermogonium

growing in almost straight lines towards the centre. When maturity is reached the spermogonium opens at the top, and the contents burst through the epidermis of the barberry leaf, as shown. At the time of bursting, the little dark central mass turns up towards the burst point, and the growth of the spermogone threads is continued through the orifice, as shown at HH. The septate spermogone threads, after they have reached the air, break up into

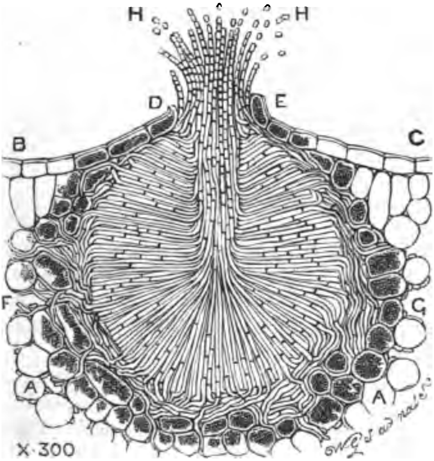


Fig. 85.
Section through a Spermogonium of *Æcidium Berberidis*, Pers. Enlarged 300 diameters.

extremely small granules, and these granules are the *spermatia* of botanists. They are supposed to be little grains belonging to a male organism, roughly answering to the pollen of flowering plants. Most of the illustrations of *Æcidium* spermogonia hitherto published are incorrect.

After the *Æcidium* cups and spermogonia are once formed, most of the mycelium amongst the cells of the leaf,

from which the cups and spermogonia arose, breaks up into the finest conceivable dust, or dissolves away, and so is lost to sight.

A single *Æcidium* spore is enlarged to 1000 diameters at Fig. 86. To the spore are attached four of the so-called

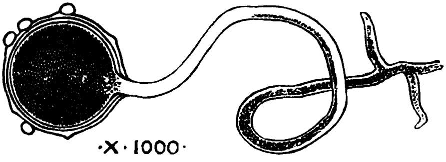


FIG. 86.
Germinating spore of *Æcidium Berberidis*, Pers.
Enlarged 1000 diameters.

spermatia from the spermogones, just as one commonly sees pollen-grains agglutinated on to a stigma.

The spores germinate rather sluggishly on damp surfaces, but when seen in a state of germination a mycelial thread is protruded in a convolute fashion from one of about six privileged or weak points on the surface of the spore. Into the mycelial thread the vital material from the spore is poured.

The tardy germination of the spores seems to indicate that they are of the nature of resting-spores, and therefore able, under suitable conditions, of resting for a prolonged time. It is generally believed that the spores arise from male and female elements, and these facts indicate to some observers that the cycle of the *Æcidium* is complete in the production of these spores, or that no other spores are likely to exist unless simple conidia or bud spores, as opposed to resting or sexually-produced spores.

Of late considerable attention has been directed to the fact of the occurrence of *Æcidium Berberidis*, Pers., on the more ornamental species of barberry of our gardens and shrubberies, and especially its growth upon *Mahonia Aquifolium*, Lindl. The rare occurrence of the parasite

upon other barberries than the wild barberry of Britain has long been well known. A short paper from the pen of Mr. Charles B. Plowright, M.R.C.S., has been published in the *Proceedings of the Royal Society*, No. 228, 1883. In this paper Mr. Plowright considers he has proved by experiment that the *Æcidium* upon *Mahonia* is one condition of the summer mildew of corn, *Puccinia graminis*, Pers. Mr. Plowright kindly furnished us with numerous examples of *Mahonia* berries on which the *Æcidium* was growing, not only upon the exterior of the berries, but sometimes upon the seeds exposed in berries burst by the

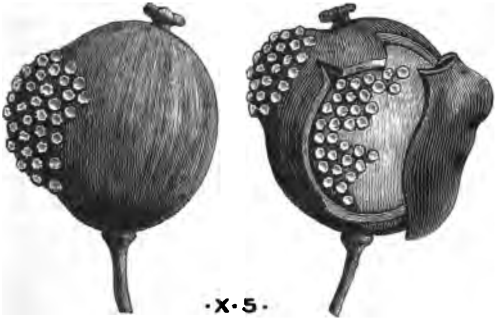


FIG. 87.
Berries of *Mahonia Aquifolium*, Lindl., invaded by *Æcidium Berberidis*, Pers. Enlarged 5 diameters.

growth of the fungus. Doubtlessly the *Æcidium* cups grew on the seeds after the berries were burst. Two *Mahonia* berries badly infested with the *Æcidium* are illustrated at Fig. 87, enlarged five diameters. The presence of the fungus, as is usual, causes hypertrophied or greatly swollen places on the affected part. We shall refer to Mr. Plowright's communication further on; in the meantime we point out that the parasite sometimes occurs on the leaves and petioles, as well as the berries of *Mahonias* and the other ornamental species of garden barberries.

Here we come to a halt similar to the one we came to at the conclusion of the description of *Puccinia graminis*, Pers. Some botanists believe that *Æcidium Berberidis*, Pers., is probably complete in itself, others state that the *Æcidium* spores will not enter the organs of transpiration of barberry leaves, but will only enter the stomata of grasses, and that then they produce, not an *Æcidium*, but a *Uredo*, viz. *Uredo linearis*, Pers., the first stage of the fungus of the summer mildew of corn,—*Puccinia graminis*, Pers. It will be remembered that a similar phenomenon was said to hold good with the fungus of spring mildew of corn and the fungus of borage blight.

We will now impartially review the evidence brought forward on both sides of this disputed question, withholding nothing—as far as our knowledge goes—for or against the alleged connection of *Puccinia* and *Æcidium*.

CHAPTER XXV.

THE POSSIBLE CONNECTION OF THE FUNGUS OF CORN MILDEW AND THE FUNGUS OF BARBERRY BLIGHT.

In the following review of the evidence for and against the connection of the fungi found under the genera *Puccinia* and *Æcidium*, it will be understood that the remarks made in reference to the fungus of the summer rust and mildew of corn, with its supposed *Æcidium* condition on barberry bushes, applies also to the spring rust and mildew and its supposed *Æcidium* on members of the Borage family. In fact, the following notes apply to every instance where there is a supposed connection between *Puccinia* and its allied genera on the one hand, with *Æcidium* and its allied genera on the other.

First we will give a brief account of the popular belief which is said to have existed amongst rustics in old times, then we will give the evidence brought forward by some men of science as supposed proofs of an actual connection of corn mildews with the blights of barberry and borage; and, lastly, we will state the reasons why other men of science in some instances reject the evidence of the supposed connection, and in other cases consider the connection as unproven. As each of these branches of the subject are reviewed we will state how our mind has been impressed by the statements. The readers of this chapter may then form their own opinion as to the value of the facts as well as of the deductions which have been either reasonably or unreasonably drawn from them.

The first we hear in regard to the connection of corn

mildew and the blight of barberry bushes is a popular belief, said to have been common amongst rustics in old times, that barberry bushes blighted corn. Now, although popular beliefs peculiar to rustics of the last century need not be altogether disregarded, yet we are inclined to put a low estimate upon them. The rustics of the last century did not always fix on the barberry bush as a supposed cause of corn mildew, for in some districts old hawthorn bushes were believed to be the cause; and to this day the labourers of some parts of the eastern counties, as in the Hardingham district, believe hawthorn bushes to be the cause, or, if not the sole cause, to be at least equally pernicious to corn with the barberry bush itself. The barberry is not everywhere considered by rustics to be capable of causing corn mildew. In some districts the barberry is said to be the cause of *Bunt*, a disease of corn described further on in this work. This belief was at one time very prevalent on the Continent, and is described by Phillipar in his *Traité Organographique et Physiologico-Agricole sur la carie, le Charbon, l'Ergot, la Rouille, et autres Maladies du même genre qui ravagent les Céréales:* Versailles, 1837. The division of opinion amongst rustics appears to us to militate against the acceptance of one particular view and the rejection of the others. Rustics of the last century were very superstitious, and the farm labourer whose family was destroyed by ergot in the last century (referred to in this work under "Ergot") would not believe that bad wheat was the cause of the limbs of his family rotting off, but insisted on the cause being witchcraft. No one at the present day would consider the exploded idea of witchcraft supported by this old belief of rustics, and we are inclined to give no better credence to the ideas of rustics as to the connection of corn mildew and bunt with barberry and thorn bushes. The farm labourers possibly noticed that the colour of the fungus of rust of corn and that of the fungus of barberry blight was the same, and this may have led them to connect the two. When the barberry is in flower

it gives out an unpleasant odour; and as the fungus of bunt also gives out an offensive scent, it is quite possible that the similar strong odour belonging to both parasites at one time led rustics to connect barberry blight and bunt together.

In past times rustics not only believed in witchcraft and magic, but they, as we all know, had strange beliefs regarding the influence of the moon on the weather, and other old beliefs which now prevail to a less extent. No one would now think of bringing forward these absurd old beliefs in support of the more exact astronomical and meteorological knowledge of recent times.

In the agricultural journals of the last hundred years many curious observations may be found from the pens of sharp observers, who really thought the connection of corn mildew and barberry blight to be proved. Other observers, however, and equally sharp ones, have brought forward evidence of an entirely opposite character; so that nothing has been proved from old experience either for or against the connection. Mr. C. B. Plowright, in a valuable paper published in the *Gardeners' Chronicle* for 19th August 1882, has given all the popular evidence that he could collect in favour of the barberry being injurious to corn; but this gentleman has not referred with equal fulness to the popular evidence that told the other way. Prof. J. S. Henslow, writing in the *Journal of the Royal Agricultural Society* in 1841, vol. ii. p. 13, said that practical men were by no means unanimous in denouncing the barberry. An experienced cultivator of Hamburgh is referred to in that paper, who, after observations made for thirty-one years, expressly contradicted the commonly-received opinion. Experiments are recorded by Professor Henslow which were made at Copenhagen. Wheat was there planted and surrounded by barberry bushes without obtaining any mildew. A similar experiment was made by Jussieu in the garden of Trianon with a like result. Mr. Knight also only obtained a negative result with experiments of the same class. Mr. Henslow

states that he only knew of a solitary instance of barberry bushes growing near corn, and there the corn was worse mildewed than elsewhere, not because of the juxtaposition of the barberries, but because the bushes were at a corner of the field where the soil was decidedly the worst, and where the corn was sheltered by lofty trees. Other observers, and equally reliable, have given evidence of a positively opposite character,—one agriculturalist going so far as to state that he had never even seen corn growing near a barberry bush without its being injured more or less. Phillipar, in the work already quoted, says, in reference to corn mildew and barberry blight, that he was never able to meet with sufficiently conclusive evidence for a conviction of the barberry. On the contrary, he states that he has seen many instances in which hedges were filled with barberry bushes, without the corn, which was near them, having sustained the slightest injury. Nothing can be made of the old agricultural evidence, for what is stated by one side is soon after flatly contradicted by the other.

Sir Joseph Banks was one of the first to suggest that the yellow fungus of the barberry might be another form of the rust fungus of corn, but this was only a guess on Sir Joseph's part, founded on a popular belief. A very early reference to the supposed injurious effect of the barberry on corn may be found in Krunitz's *Encyclopedia,* 1774.

Mr. Wm. Carruthers, F.R.S., in his paper on wheat mildew published in the *Journal of the Royal Agricultural Society,* ser. 2, vol. xviii., part. ii., p. 495, brings forward an instance (quoted by Professor Henslow) in favour of the connection of corn mildew and barberry blight; but he omits the opposing evidence as printed in the same paper. In the particular instance quoted by Mr. Carruthers the cornfield was bounded in one part by a "young and healthy quickset hedge;" here it is presumed there was little or no mildew; but in another part of the field there

was an "old hedge with several barberry and other bushes and some elm trees." The account continues: "It is true the current of air was somewhat impeded by the trees." In Mr. Carruthers' paper this important sentence is not given, although, in our opinion, the old hedge, with its variety of bushes and elm trees impeding the air, is quite sufficient to greatly favour a growth of mildew, and by no means favours the idea that the fungus of barberry blight and corn mildew are genetically connected.

We acknowledge that an opinion expressed by Sir Joseph Banks or Professor J. S. Henslow still carries more weight than the belief of rustics in the last century; but it must be remembered that in the time of Sir Joseph Banks and Professor Henslow very little indeed was known of the anatomy or physiology of fungi,—so little, indeed, that any opinion the two gentlemen above named may have expressed on this subject can only be held in slight esteem now. Men of science of the present day do not generally try to support their views by quoting what other observers thought one or two hundred years ago, particularly when those observers were not specialists. Old observers were doubtless right in many of their ideas, but no support is given to modern views by quoting the opinions of old authors who were but poorly acquainted with their subject. This course is never taken with geology or zoology—then why with the most difficult and least understood section of botany?

We consider, then, that this part of the subject has been weakened by the attempts of some modern writers to support their opinions by quoting the views of rustics in the last century, and by printing the old ideas of Sir Joseph Banks and Professor J. S. Henslow about fungi with which they were confessedly but very imperfectly acquainted. This part of the subject is indeed, in our opinion, hardly worth consideration. Mr. C. B. Plowright, however, has gone further, and republished a *Pro-*

vince Law of Massachusetts of 1738-61, in which it is said that the "blasting of wheat and other English grain is often occasioned by barberry bushes." In the introductory remarks written by Mr. Plowright to this *Province Law,* he correctly says of corn mildew that germs of the disease "will have a greater chance of gaining admission into the interior of the wheat plants in those parts of the field where the influence of currents of air is least felt." The Massachusetts law enacted that all barberry bushes should be extirpated, as they have now virtually been extirpated in Britain. As far as is known, this "extirpation" of barberries, even when enforced by law, has not had the least tendency to lessen attacks of corn mildew. Surely the quotation of an obsolete and, as considered by many persons, a stupid old law, will not convince disbelievers in the connection of corn mildew and barberry blight that they are wrong. We might quote other old laws, such as the one regarding witchcraft, and refer to Matthew Hopkins, the professional and official witch-finder, who in the years 1644, 1645, and 1646, as recorded in Godwin's *Lives of the Necromancers*, pp. 434, 435, caused sixteen innocent persons to be hanged at Yarmouth in Norfolk, fifteen at Chelmsford, and sixty at various places in the county of Suffolk.

In approaching modern times we come to much more exact and searching evidence, and this modern work is really the only part of the subject worthy of serious attention. We have been informed by Mr. J. L. Jensen, of Copenhagen, through Mr. C. B. Plowright, that the first person who instituted scientific experiments with the fungus of corn and the fungus of barberry blight was a Danish schoolmaster named Schoeler, who lived at Hammel, in Denmark, and who, seventy years ago, placed the fungus of barberry blight on rye, and produced the rust fungus. Bönninghausen in 1819 experimented with the spores of the fungus of barberry blight by applying them to rye. In five or six days the rust fungus is said to

have appeared on the rye. The probability of the occurrence of an alternation of generations on fungi was suggested by the Rev. M. J. Berkeley in the *Journal of the Royal Horticultural Society* for 1848, where he wrote, in describing the "Bunt" fungus of wheat, "It is quite possible in plants, as well as in the lower animals, there may be an alternation of generations." In 1865 Professor A. de Bary, of Strasbourg, published an essay—*Monatsbericht der Königlichen Preuss. Akademie der Wissenschaften zu Berlin*, Jan. 1865—in which he stated that he had artificially produced the rust of wheat by placing the spores of the barberry fungus on corn. One would have naturally thought that Professor de Bary was led to make this experiment by his knowledge of the popular belief as to the supposed connection of the two fungi; but we are told by Mr. Plowright in the *Gardeners' Chronicle* for 30th July 1883 that this was not the case, but that Professor de Bary had previously experimented with a *Puccinia*, named *P. tragopogonis*, Corda, and that the little pro-mycelium spores produced by the germinating teleutospores of the *Puccinia*, when sown on a healthy host-plant, did not produce a *Uredo*, but an *Æcidium* named *Æ. tragopogonis*, Pers., and that when the *Æcidium* spores were planted on another host-plant, they in turn produced a *Uredo*. We have in this country an abundance of *Æcidium tragopogonis*, Pers., but *Puccinia tragopogonis*, Corda, is unknown. Professor de Bary, then (says Mr. Plowright), selected the barberry "because experience had taught the practical farmer that it was prejudicial to the wheat crop." This admission appears to be identical with the one suggested by us, that the experiments were undertaken in consequence of a popular belief amongst a certain number of farmers and their labourers. Professor de Bary appears to have been unacquainted with the admirable paper by Professor J. S. Henslow in vol. ii. of the *Journal of the Royal Agricultural Society* for 1841, where the identity of rust or *Uredo* and mildew or *Puccinia* was first pointed out.

Since Professor De Bary's paper was published, other good observers have made experiments, some with a result pointing in one direction, some with a result pointing in the opposite one, and others with a negative result. Many botanists hold that the case is proved, and that the connection of the two fungi is certain; others, as Dr. M. C. Cooke, one of the foremost fungologists of this country, still hold the connection of the two parasites as unproven. The latest exponent of the connection of *Uredo* with its *Puccinia* and *Æcidium* is our friend Mr. C. B. Plowright, M.R.C.S. This gentleman has made two sets of experiments. In the first his results were negative, or, as he himself says, they seemed to show that the barberry fungus had very little to do with corn mildew. In the first series of experiments in which spores of *Æcidium Berberidis*, Pers., were placed on wheat plants, 76 per cent became infected with rust, and amongst the wheat plants which were kept as checks on the infected ones, no less than 70 per cent became spontaneously diseased with rust. After his later experiments Mr. Plowright altered his first-expressed opinion, and now he strongly advocates the connection of the two parasites. We consider the published change of opinion favourable to Mr. Plowright as an observer, for it is not every one who has sufficient independence of mind to so frankly and quickly publish such a radical change of thought. Mr. Plowright is to be trusted to a far greater extent than men who have advocated erroneous theories, and then quietly ignored their former teachings without acknowledging their error. Mr. Plowright has published a series of engravings, mostly from nature, illustrative of the subject before us. All the illustrations are original but one, and that one is the crucial one of the spores of the fungus of corn mildew germinating on and sinking through the cuticle of the barberry leaf. In this illustration (*Gardeners' Chronicle*, 19th August 1882, p. 233) a large open organ of transpiration is shown close to three germinating pro-mycelium

spores of the mildew fungus: the threads do not enter the open stomate, but are seen boring through the cells of the barberry leaf. This special drawing, the only one of real interest in the paper, is not original, but a copy from a published book. We consider it a weak point, therefore, in Mr. Plowright's case that in his elucidation of the only critical part of his subject he has fallen back upon a many times copied and recopied book illustration. How valuable a new illustration of this wonderful phenomenon would have been; but at present, as far as we know, no one has ever ventured on a second original representation. We do write in this way with a view to throw doubt on the accuracy of the drawing. Every one who has a microscope can easily see *Uredo* spores, *Puccinia* spores, and *Æcidium* spores germinate, and many are the original published illustrations. How is it, we may ask, then, that so few can see pro-mycelium spores piercing the epidermal cells of a barberry leaf, or, if they can so see them, do not venture on new illustrations? It was specially necessary that Mr. Plowright should, if possible, have published an original of this phenomenon.

As Mr. Plowright is now the chief teacher of the connection of corn mildew and barberry blight in this country, it will be interesting to record his words in reference to infecting barberries with spores from the fungus of corn mildew. He writes: "On 14th April, 17th April, and 9th May, respectively, I infected one of these (barberry bushes) with spores from the pro-mycelium of *Puccinia graminis* from wheat and twitch, and kept the three remaining barberries as control plants. In due course the *Æcidium* appeared upon the infected plants, the control plants remaining free from *Æcidium*, and they continued so for two months, when they were cut down, the experiment being then ended." Further on Mr. Plowright writes: "On 15th and 17th April I placed upon nine wheat seedlings some of the same pro-mycelium spores which were used for infecting the barberries, and upon 7th May one of the wheat plants

had rust or *Uredo* upon it. As these plants were, however, exposed to the air for fourteen days, an element of doubt is admitted, *although an equal number of check plants grown in the open air in the same garden remained free from rust.* (The italics are ours.) That they did not contract the parasite from the barberries in my garden is clear from the fact that there were no *Æcidium* spores there until many days later." Surely the evidence in this test case shows, if it shows anything, that Mr. Plowright really and truly produced the *Uredo* from the *Puccinia* spores. He admits there were no *Æcidium* spores; he experimented with germinating *Puccinia* spores only, on wheat, and *Uredo* was the result. Bönninghausen gave the time of the appearance of the disease after infection as five or six days; Mr. Plowright states twenty or twenty-two days.

The gentlemen who advocate the connection of wheat mildews with barberries and borages bring forward the following fact, which, it must be acknowledged, has considerable weight. On repeating experiments first made on the Continent with *Puccinia* and *Æcidium* spores one or two species of fungi have appeared (presumably as the result of the experiments) which had hitherto been unrecorded as British. Undoubtedly, this fact is of importance in the consideration of the subject; still it must be borne in mind that whilst fungologists are few fungi are almost without number. No season passes but large numbers of species new to Britain are added to our flora. In fact it seems to be true in regard to fungi that one has only to look for certain species in the right places and at the right time, and they are certain to be found. Not only are numerous small leaf fungi annually lighted on, but large species, sometimes a foot high, as *Morchella Smithiana*, Cke., by ourselves, and *Lactarius controversus*, P., by our friend Dr. M'Cullough of Abergavenny. No one supposes these large fungi did not exist here before; they were not seen and recorded, simply because no one had looked for them. Prof. Elias Fries, the illustrious Swedish botanist, wrote us, a short time

before his death, to say that he believed a large number of his Swedish firwood fungi would be found in the firwoods of Scotland if sought for; but they are still but little sought for, and therefore not in many instances found.

There has long been an extremely common fungus in this country named *Æcidium Tussilaginis*, Pers., but till lately its supposed alternate form, *Puccinia Poarum*, Niel., had not been recorded, although the host plant of this fungus is extremely common. Mr. Plowright in his experiments (*Grevillea*, vol. ii. p. 56) claims to have produced this *Puccinia* artificially on *Poa* eleven days after infection from the germinating *Æcidium* spores; and on close search being made, examples of *Poa annua*, L., were found growing naturally and bearing the *Puccinia*. These facts as to the artificial production and the ultimate discovery of the naturally-grown *Puccinia* have been brought forward as evidence in favour of the connection of *Æcidium* and *Puccinia*. We are inclined to give but little weight to this part of the evidence, for the *Æcidium* still remains extremely common and the *Puccinia* extremely rare, just as in the common *Uredo Rubigo-vera*, D.C., and the excessively rare *Æcidium asperifolii*, Pers., described in this work under Spring Rust.

The believers in the connection of corn mildew and barberry blight consider their views supported, and indeed proved, by their experiments. The results of the experiments leave no room they say for doubt; still a great difficulty rests with all the experiments in regard to the lapse of time which takes place between the application of the infecting spores and the appearance of the fungus which is supposed as a consequence to follow; this period is sometimes more than twenty days. In the case of *Æcidium bellidis*, D.C., as reported in the *Journal of the Linnean Society*, vol. xx. p. 512, the time ranged from twenty-four days to over two months. When a germ tube enters the tissues of a plant through one of its organs of transpiration, no one can follow it farther. Every microscopist knows that a leaf is an opaque object, and no amount of

artificial light will show what has become of a germ tube from a fungus spore when it has once travelled down amongst the constituent cells of the leaf. If a germ tube of any given fungus is known to have entered a leaf, and a fungus of a totally different nature appears in eight days or two months afterwards upon the surface of the invaded leaf, where is the clear proof that the foreign germ tube really caused the production of the new fungus-growth? It is certainly not impossible that one may have arisen from the other, but the proofs of a phenomenon so wonderful should be unimpeachable,—proofs such as no one could possibly doubt or question.

The believers in the connection of corn mildew with barberries always recommend the destruction of barberries as a preventive of corn mildew, and Mr. Carruthers, in the paper already adverted to, writes: "The farmer should not permit the barberry to have a place in his hedges or in plantations on his farm." At one time barberries were abundant in Britain, now they are very rare in a wild state, and as a rule only to be seen in single isolated examples. As the former extirpation of the plant has not lessened the mildew of corn in the slightest degree, why then should the remaining few barberry bushes be destroyed, especially when the case of Australia and New Zealand, where, with a total absence of native barberries, corn mildew is worse than in Europe, is remembered? In our own country corn mildew is notoriously at its worst in the fen districts, where the barberry is absent in a wild state. The advocates of the connection of the two fungi acknowledge that mildew is perennial in corn; being so, the *Æcidium* condition on barberries, even if admitted as a condition of corn mildew, cannot be a *necessary* condition. With the destructive fungus of spring mildew of corn and its supposed *Æcidium* on borages, the case is still more striking. There is no need to tell farmers not to allow any members of the Borage family to have a place in their gardens; it does

not matter what number or variety of borages they grow, for however large the number may be, they are almost sure to have no *Æcidium* upon them. *Æcidium asperifolii*, Pers., is so rare in Britain that during a thirty years' study of fungi we have never once met with it. On inquiring, as to the prevalence of this fungus in Britain, of our friend Dr. M. C. Cooke, he replied that he had carefully sought for it, but had only found it about two or three times in twenty years. Mr. C. B. Plowright, who wished to experiment with it, could not get it here at all, and the illustrations in this work, Fig. 70 and Fig. 71, were taken from a dead foreign example, simply because no British or living specimen could be secured. Some persons may think from this, that spring rust of corn derives but scant benefit from a possible connection with a fungus of such extraordinary rarity as *Æcidium asperifolii*, Pers. It is clear that the rust can keep in existence for an indefinite time without any aid from the *Æcidium*. *Puccinia Rubigo-vera*, D.C., and *P. graminis*, Pers., are very close allies, and both grow upon the *Gramineæ* or grasses; one would have expected, therefore, that their alternate *Æcidium* forms would both grow on one plant or set of allied plants. We have seen, however, that such is said not to be the case, as the *Berberidaceæ* and *Boraginaceæ* are widely separated.

Notwithstanding these objections we are not inclined to attach undue importance to the absence of *Æcidium Berberidis*, Pers., in Australia, or to the extreme rarity of *Æcidium asperifolii*, Pers., here. The spores of these fungi may possibly be more common in some other country, and be carried through the air from one place to another. Clouds of aphides and ladybirds have sometimes been seen darkening the air and travelling towards Britain across the sea from France, and spores may travel in the same way or be carried by insects, birds, or man. We do not, however, consider such a transport of spores, especially across the ocean to Australia, probable, though not per-

haps impossible; and there is no proof that anything of the sort has ever occurred.

We have little doubt that the mycelium of both the mildew fungi and the spawn of both the *Æcidia* are perennial, and that both can live on from year to year for an indefinite period without aid from each other. Mr. Berkeley, in vol. i. of the *Journal of the Royal Horticultural Society*, writes at p. 25: "The mycelium of cereal fungi is known to exist from the earliest period in corn;" and further on he remarks that "a diseased stock can scarcely be expected to produce a perfectly healthy offspring," and "it is certain that the germs of cryptogamic plants may be present in tissues, and yet remain more or less inert." Referring to *Æcidium*, he says, in reference to the parasite of the anemone (*Introduction to Cryptogamic Botany*, p. 323), "the leaves, which will be eventually covered with the fungus, show that they are impregnated with its mycelium as soon as they make their appearance." If these facts are admitted, and *Æcidium quadrifidum*, D.C., of the anemone is acknowledged to be perennial, another point arises. How can any observer tell that the plants he is experimenting with have not the germs of disease already in their tissues? We, as well as many other observers, have shown that seeds apparently sound will often, on germination, show disease in their seed leaves; such plants are saturated with the germs of disease from their earliest period of growth.

An instance was adverted to by us in the *Gardeners' Chronicle* for 26th January 1884, p. 120, where a well-known nurseryman in a large way of business had imported *Dianthus* seeds direct from Japan. These seeds were carefully grown under glass, and, immediately they were up in the seed-pans, they were all attacked and destroyed by *Puccinia lychnidearum*, Link. On making a microscopical examination of a series of these seeds we detected mycelium inside the integument which surrounds the embryo or infant plant and within the coat of the seed.

Dr. M. C. Cooke has published a case where seeds

gathered from undiseased celery plants produced healthy plants; whereas seeds taken from celery plants diseased with *Puccinia Apii*, Corda, produced seedlings every one badly infested with the *Puccinia*. The plants were grown in rows side by side in the same garden, and the clean plants remained healthy all the season; whereas the diseased ones were destroyed by the hereditary disease derived from the parent plants and presumably conveyed from the parent to the offspring in the seeds.

The Rev. M. J. Berkeley has published in the *Gardeners' Chronicle*, 28th October 1848, p. 716, an instance of plants of *Pyracantha* raised from seeds imported from Russia being all killed by a species of *Fusicladium;* whilst old plants of *Pyracantha* growing at the same place remained perfectly free from disease. The same gentleman records an instance of a plant of *Achillea Ptarmica*, L., being given to him by M. Desmazieres. When presented it was apparently quite free from disease, but the donor knew that the disease plasma of *Labrella ptarmica*, Desm., was in its tissues. The *Achillea* was planted in March, and in the following autumn the *Labrella* duly appeared, although the fungus up to that time had not been seen in Britain. It is common to find hollyhock seedlings showing the *Puccinia* on their seed leaves. This we have traced to the presence of pustules of the disease outside the seeds or carpels, as illustrated by us in the *Gardeners' Chronicle* for 1st July 1882, p. 23. Similar pustules occur on the carpels or seeds of wild mallows.

Many similar instances might be given; they all prove that *Puccinia* on mildew is hereditary,—that it exists in a finely-attenuated state in seeds taken from diseased plants, and can be transmitted in a long interminable line from generation to generation. No doubt it is possible that living spores or mycelium may sometimes be present outside the seeds, but many fungi are able to reach the seeds, as the fungus of bunt in corn, *Tilletia Caries*, Tul., and *Thecaphora* within the carpels of convolvulus, etc.

We believe we have seen instances of the spawn of the *Æcidium* being perennial in the barberry. The mycelium which gives rise to rust and the mycelium from which *Æcidium* arises hardly appear to us to be of the same nature. Attention has lately been redirected to the occasional growth of *Æcidium Berberidis*, Pers., on garden barberries, especially on *Mahonia Aquifolium*, Lind. It has been suggested that there may be garden barberries in Australia, and that these plants may be infested with the *Æcidium* said to belong to corn mildew. This may possibly be correct, although no evidence has at present been forthcoming in that direction. If garden mahonias are found to bear *Æcidium* in Australia we imagine the number of diseased garden mahonias on that large Continent will be in about the same proportion to the vast cornfields there found, as the borage *Æcidium* is to the cornfields of Britain, or as the fungus of *Poa annua*, L., is to the *Æcidium* of coltsfoot and butter-bur.

Mr. Charles B. Plowright was kind enough to send us a good collection of *Mahonia* berries invaded by *Æcidium*, as illustrated in Fig. 87. Occasionally the disease appeared upon the leaves and stalks, and from our examination of them we were inclined to think the mycelium of the fungus traversed the entire plant, and especially the berry with its seed. We successively planted a number of seeds at overlapping intervals through last summer, but not one germinated. This suggested to us that the plasma of the fungus had reached the embryos of the seeds and killed them. On inquiring of Mr. B. S. Williams, the well-known nurseryman of Upper Holloway, he informed us that *Mahonia* seeds germinate freely when the seed has been matured, is good, and properly planted. Mr. Williams said *Mahonia* seeds took from two to three months to germinate, and he kindly undertook to test twelve ripe berries for us, each berry showing the *Æcidium* disease. The seeds were sown carefully in two pots, and after the proper time had elapsed no single seed

showed the least sign of germination, but all had perished. These facts, of course, do not prove that the mycelium is perennial, but we think it proves that the spawn can reach the embryo of seeds, and in bad cases kill them. We also think it suggests the possibility of seeds less badly diseased being able to give rise to diseased seedlings, exactly as in the case of the *Dianthus* seeds, which showed the *Puccinia* in the seed-leaves. In the *Proceedings of the Royal Society*, No. 228, 1883, Mr. Plowright has illustrated the *Æcidiospores* belonging to *Mahonia Aquifolium*, Lind., germinating upon the epidermis of a fragment of wheat-leaf. Six spores are shown: five are germinating—three germinal threads are entering the stomata; but no less than seventeen little branches of the mycelium are shown naturally and correctly running along the little furrows belonging to the junctions of the cells which form the leaf cuticle. The illustration simply proves that the germ-tubes will run anywhere where there is a depression, or run into any little orifice. After eleven days, not five or six as with Bönninghausen, *Uredo* appeared upon the plants experimented upon.

Many cases are well known where host plants are always so saturated with parasitic disease that it is almost impossible to find the host without the parasite. *Pythium equiseti*, Sdbk., is so common on *Equisetum* that we have seldom found an *Equisetum* without it. Cress seedlings are plagued in a similar fashion with another *Pythium*. Now, who would place any reliance on experiments made with a view to inoculate *Equisetum* and cress with *Pythium*, when it is well-known beforehand that every plant is probably already permeated with the virus of the parasite in a latent state?

Personally we do not esteem the fact of spores germinating on the cuticle of a leaf as of the slightest value. Nearly all spores will germinate in warm moist air upon any surface, and the spawn-threads will run into any slight depression, or any orifice, provided it is large enough.

Germinating spores of *Uredo*, *Puccinia*, and *Æcidium* traverse the scratches made by a lancet on our glass slides just as naturally as if they were the furrows of a leaf-cuticle. When the threads get to the edge of the glasses they dip down just as naturally as if the vacant space were an open organ of transpiration. We have grown spores on moist linen, calico, and blotting-paper, and the germ-tubes have penetrated between the orifices and run over the reverse side just as if they were in a leaf. Such spores, unless of moulds, of course do not reproduce a perfect fungus like the one from which they originally arose; neither do those sown on leaves. Professor De Bary says he could not cause *Æcidium* spores to grow effectually on barberry leaves. It is only after a considerable time has passed, and the germ-threads have been lost to sight for many days, several weeks or months, that some new fungus of an apparently different nature at length appears.

One writer has said that botanists were prepared to accept the idea of *Puccinia* and *Æcidium* being one and the same fungus because they were acquainted with the changes of some insects such as are familiar in the caterpillar, chrysalis, and perfect butterfly in the insect world. We confess that we do not see the resemblance at all. No condition of the insect is ever lost to sight for ten or twelve days or two months, and the change is gradual throughout from one form to the other; the chrysalis is foreshadowed in the caterpillar, and the perfect butterfly has all its parts in the chrysalis. No organisms belonging to *Puccinia* are ever indicated by *Æcidium*, and no analogues of *Spermogones* or *Æcidiospores* are ever met with in *Puccinia*.

It has been stated by Professor De Bary that an analogous case of the change of host exists in the animal kingdom, as in the case of the entozoic worms, which pass the first part of their existence in one animal, and the second part in another and totally different animal. The experiments with entozoic animals have doubtlessly proved

this fact; but to compare the facts belonging to the animals with those belonging to the plants is a case of mistaken analogy, for the facts do not correspond.

In the first place, the test experiments with *Entozoa* have invariably been made with host animals that were perfectly well known to be quite free from entozoic parasites. Measures have always been taken to make this fact certain before the experiments were commenced. The two series of animals have in no single instance been notoriously infested with parasites before the experiments were entered upon.

The comparison that has been made between the change of host in the *Entozoa*, and the supposed similar change of host in the two parasitic fungi of spring and summer mildew of corn, brings us to what we think may prove a fatal objection to the connection of *Puccinia* with *Æcidium*, and one that strikes at the root of the whole hypothesis. In the entozoic animals referred to, one form of the parasite, say of the liver-fluke of sheep, is sexually mature in a certain mammal. These sexual individuals, which produce thousands of eggs, escape by the alimentary canal of the invaded animal. The eggs are dispersed by wind, rain, insects, feet of cattle, and other means, and so at length find their way into pools, ponds, and streams. The mature eggs contain ciliated embryos, which are set free on moist surfaces or in water. Each embryo contains a bud which at length becomes a larva. The ciliated embryo attaches itself to a second host, such as a snail, slug, or aquatic insect, and so gains access to the interior of the new host. In this position it becomes a non-sexual larva, and capable of producing a progeny, or other larvæ, within itself. These secondary larvæ migrate from the bodies of the water insects or molluscs and become free; they are then swallowed by mammals whilst eating or drinking. The larvæ now bore through the tissues of the new host, and enter into a pupa stage whilst within the mammal, and there at length become sexually mature egg-producers, and so the life cycle becomes complete.

Now we will note how the phenomena connected with *Æcidium* and *Puccinia* agree or disagree with the entozoic life-history just given. We commence with the *Æcidium*. Here we have a sexually mature parasite, with so-called *spermogonia* and *spermatia*. The names indicate male organs, with a male fertilising element analogous with pollen. Mr. Plowright, in writing of the spermogonia and spermatia, says: "Their function has not as yet been absolutely demonstrated, but there is little doubt that they play the part of the male element." It is necessary to be exact at this point, for if there is a sexually perfect state of the parasite it must of course be either in the *Æcidium* or the *Puccinia*; and if the *Æcidium* breaks down, the whole hypothesis falls to pieces as far as published descriptions go.

We believe the *Æcidium* to be sexually perfect, as indicated by the descriptive terms in general use. The male organs or spermogones are usually, if not invariably produced first, and the *Æcidia* next; this phenomenon roughly agrees with the sequence of the stamens and pistils in flowering plants. In *Endophyllum* and *Rœstelia* the spores resemble the oospores of a *Peronospora*. We believe that the spores with spermatia attached, as illustrated in Fig. 86, agree with fertilised ovules. These fertilised ovules, if they agree in habit with the ova of *Entozoa*, should produce a simple larval form, which should reach the interior of some other plant and there live parasitically as a larva. The spore of the *Æcidium* is supposed to so reach the leaves of corn, and to travel to the interior by the stomata. In this position we presume it resembles the non-sexual larva inside the snail. In the entozoic animals in question the larva never reaches any higher stage in its host, the snail: it attains its pupa and perfectly sexual state when it again reaches the mammal. Here the comparison appears to break down; neither the *Uredo* or *Puccinia* can be larval. A larva in fungi can only be some simple conidioid form like the *Oidium* of

grass mildew—some simple, budding, non-persistent, non-sexual form.

The *Uredo* and the *Puccinia* which follow the *Æcidium* are the reverse of simple, the *Puccinia* being specially complex and persistent. The *Uredo* is surely the pupa state of the *Puccinia*, and Mr. Plowright himself, in describing the teleutospores of the latter, correctly, as we think, terms them resting-spores. Resting-spores they certainly are, for many of them rest for nearly a year before germination takes place. They are as truly analogues of ova or eggs as are *Æcidiospores.* If *Puccinia graminis*, Pers., is the larval state of *Æcidium Berberidis*, Pers., it is at least curious that the larvæ should be so extremely and continuously prolific in Australia, whilst the sexually mature form is restricted to the other quarters of the globe.

If the teleutospores of *Puccinia* are resting-spores or analogues of oospores, as they probably are, the spores of *Æcidium* cannot be of the same nature without there being two sexually mature egg-producing forms in the same life cycle of the fungus. We lately addressed a question to Dr. T. S. Cobbold, F.R.S., probably our highest living authority on *Entozoa*, and asked if he knew of any instance in the animal kingdom of a parasite passing two stages of its existence in two different animals, and arising from two different forms of eggs. Dr. Cobbold replied at once: "I give a distinct negative to your question, without prejudice to the proven fact of dimorphism amongst parasites; and of course also without the slightest reliance on the authority of Mèguin, whose erroneous views imply the belief that two sorts of eggs may belong to parasitic conditions of one species." It appears from this answer that the erroneous views of Mèguin may be comparable with the views held by many botanists in regard to *Puccinia* and *Æcidium*.

The change of host plants in fungi has been technically termed *heterœcia* and *metœcia*, from *heteros*, diverse or variable, and *meta*, a change.

The accompanying illustration, Fig. 88, is copied from Tulasne's paper in the *Ann. des Sc. Nat.*, 4 ser., vol. ii., 1854, pl. 9, and represents at A the germination of a spore of *Uromyces appendiculatus*, Lev., and at E the germination of a spore of *Æcidium Euphorbiæ-sylvaticæ*, D.C.

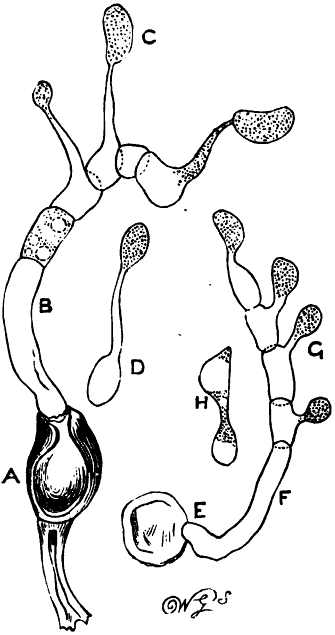


FIG. 88.
Spores of *Uromyces appendiculatus*, Lev., and *Æcidium Euphorbiæ-sylvaticæ*, D.C., germinating and producing pro-mycelium, pro-mycelium spores, and sporidioles of identical character. After Tulasne.

The illustration is copied to show that, according to Tulasne, not only is *Puccinia* capable of producing pro-mycelium and pro-mycelium spores, as shown in Figs. 69

and 81 in this work, but that *Uromyces* and even *Æcidium* itself *are both potentially capable of giving rise to precisely the same growths.* The pro-mycelium and pro-mycelium spores of *Uromyces* are shown at B and C, and the same growths belonging to the *Æcidium* at F and G. The phenomena are also exactly the same in regard to the habit of pro-mycelium spores; one belonging to *Puccinia graminis*, Pers., as illustrated by Tulasne, is shown germinating and producing a sporidiole (as Tulasne terms it) at D, and a pro-mycelium spore of *Æcidium* is producing a sporidiole of precisely the same class at H.

It may be well here to glance at the development of the teleutospores in *Puccinia.* We will take *P. Rubigo-vera*, D.C., as an example. The teleutospores, which are preceded by simple *Uredo* spores, first appear as short stalks capped by a small cell, as at A, Fig. 89, enlarged 500 diameters. At first the young teleutospore somewhat resembles a *Uredo* spore as illustrated. Although this young teleutospore looks like a *Uredo* spore in size and shape, it is in reality quite different in nature. Botanists familiar with these bodies can instantly recognise the two forms. *Uredo* is probably a pupa state of *Puccinia;* we do not say *Puccinia* needs a pupa state, but that a state analogous to a pupa stage often occurs, and is certainly present in both the species of *Puccinia* which cause mildew of corn. In an early stage of growth the young teleutospore has but one cell-wall, and the material within is a watery fluid. As growth progresses the spore is seen as at B, with a new growth springing from the base within the original cell; this growth goes on till the spore resembles C; the internal mass has now formed another wall round itself within the original wall, and in the course of a few days the new inner cell will nearly occupy the whole of the space within the first formed cell. At this time a third growth appears at the base, as at D. This growth often pushes the first inner cell aside, as shown, giving the one-sided appearance often so common in *Puccinia* spores.

As the new growth enlarges, the appearance of the teleutospore resembles E, with the upper segment dark in colour, and the lower one light. F and G show other conditions of this stage of growth, the lower cell pushing the upper one aside in an irregular manner; sometimes the upper cell becomes large and brown, whilst the lower one remains small and almost colourless, as at H. A per-

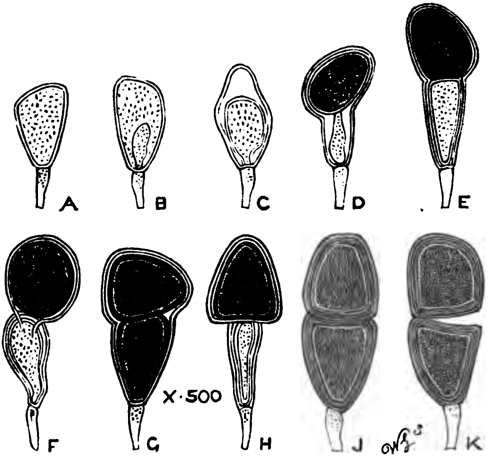


FIG. 89.
Development of teleutospores in *Puccinia Rubigo-vera*, D.C.
Enlarged 500 diameters.

fectly formed teleutospore is shown at J, and a ripe example breaking into two portions at K. The two cells of the teleutospore do not arise from a differentiation of the cell contents, and the ultimate formation of a septum. There is no septum in the outer wall of a teleutospore till the two internal cells are mature.

We are uncertain of the exact meaning that should be attached to the two contained cells in *Puccinia* spores; but

we are inclined to look upon the upper and first-produced dark cell as female, and the lower, often smaller, and more transparent cell as possibly sometimes male. It is known that the lower cell is from the first often smaller and much more transparent than the upper one. It is the upper one that usually produces pro-mycelium. When both cells produce pro-mycelium, as they frequently do, both are female. We believe it to be possible that impregnation from a male element is not necessary for every generation, but that fertile female spores may be produced for several generations without impregnation from a male organism. A comparable case of involved sexuality occurs amongst molluscs. Many land snails are monœcious—that is, each individual is male and female in itself, and capable of fertilising itself. The character varies in different genera. In the *Valvatidæ* the individuals which are at first male ultimately become female. A similar phenomenon may possibly hold good in *Puccinia* and its allied genera. A comparable phenomenon is common and well known in plant-lice or Aphides. Mr. G. B. Buckton, F.R.S., writes that in some instances "males occur only at such remote intervals that their action seems to exist at a minimum."

We do not say that the involved changes advanced by some botanists are impossible in the life-history of a single fungus, but we have shown that they are unnecessary, as *Puccinia Rubigo-vera*, D.C., can apparently reproduce itself for an indefinite period of time in Europe without an *Æcidium* condition; *Puccinia graminis*, Pers., can do the same in Australia; the allied *Podisoma Juniperi-Sabinæ*, Fr., does so in America. *Chrysomyxa Ledi* does so in Greenland, and *Puccinia obscura*, Sch., in America, where the daisy, on which its supposed alternate form is said to grow, is not found in a wild state.

To us the pro-mycelium, pro-mycelium spores, and sporidioles, potential in *Puccinia* and *Æcidium* alike, tell strongly against the idea of the genetic connection of the

two fungi. One may reasonably ask which is the sexually mature condition in *Puccinia* and *Æcidium.* If there is any meaning in the words *spermogone* and *spermatia*, *Æcidium* must be the sexually mature condition; yet the believers in the connection make *Puccinia* the perfect condition, for in describing these fungi the fruit of the *Æcidium* is invariably termed "the *Æcidiospore* of the *Puccinia.*" This puts *Puccinia* in the foremost position, and Sachs, in his *Handbook*, Ed. i., p. 247, prints "*Puccinia graminis*" under an illustration which includes *Uredo linearis*, Pers., *Puccinia graminis*, Pers., and *Æcidium Berberidis*, Pers.

When the teleutospores germinate they produce the so-called pro-mycelium spores or larval spores, as illustrated at C and G, Fig. 88. These latter spores, when they in turn change by germination, should give rise to the *Uredo* spores or pupa state of the *Puccinia.* If this view is correct, we have every life-stage perfect.

1. *Puccinia*, the perfect resting-spore stage.
2. *Pro-mycelium spores*, the larva stage.
3. *Uredo*, the pupa stage.

What need is there for another set of spores as found in *Æcidium*, with their resulting pro-mycelium spores and sporidioles of precisely the same class?

At this stage of the inquiry the question presents itself to us—If the *Æcidium* and *Puccinia* are not physiologically related to each other, how is it that *Uredo*, *Puccinia*, and *Æcidium*, sometimes grow together on the same host? Our reply is:—It may possibly be a mere state of consortism—another of the many familiar instances of two diverse organisms being found in company. The consortism, if such it be, would not be more remarkable than the consortism of *Peronospora parasitica*, Pers., with *Cystopus candidus*, Lev., on the cabbage tribe; of *Peronospora nivea*, Ung., and *Protomyces macrosporus*, Ung., on umbelliferous plants; of *Peronospora infestans*, Mont., and *Fusisporium Solani*, Mart., on potatoes; of *Saprolegnia ferax*, Kutz., and *Empusa muscæ*, Cohn; and many other

cases might be added. Another instance is met with in the *Sclerotium*, which produces *Peziza tuberosa*, Bull ; this is generally found in company with the black, horizontal rootstock of *Anemone nemorosa*, L. At one time a relationship was suspected. Plant-lice and fungi often consort curiously together. Passarini has said that the Aphis, named *Rhopálosiphum dianthi*, Sch., gives rise to a kind of mould on greenhouse plants which the French name *Fumagine*. This is the dark-coloured fungus named *Fumago* by botanists. A fungus which is extremely common on evergreens in Britain, named *Capnodium Footii*, B. and Desm., is almost invariably accompanied by the lichen, named *Strigula Babingtonii*, B. A coccus is also almost constantly present with the fungus and the lichen ; perhaps the former, by piercing the leaves or by leaving some secretion from its body, prepares the way for the fungus and its companion lichen. In the same way as the jackal is sometimes termed "the lion's provider," so the coccus may be the provider for the *Capnodium* or *Strigula*. When the fungus and the lichen have once fixed themselves on the coccus-invaded plant, the host soon dispenses with the service of the coccus. It may possibly yet be shown that the germinating *Æcidio-spore* is the provider for the *Uredo*, or the germinating *Puccinia-spore* the provider for the *Æcidium*.

Some rustics believe that mushrooms spring from salt, because "experience has taught the practical farmer" that a dressing of salt over a non-productive pasture will generally cause a good crop of mushrooms to appear. The result in this instance, however unvarying, does not prove genetic relationship.

In some instances the occurrence of *Puccinia* and *Æcidium* must of *necessity* be a mere case of consortism, as in the familiar example of the parasites of *Allium ursinum*, L., and *A. oleraceum*, L. In this instance we have an *Æcidium*, a *Uredo*, and on the Continent (but not in Britain) a *Puccinia*, named *P. allii*, Rud., all on the

same host plant; but the botanists, who physiologically connect *Puccinia* and *Æcidium*, say the *Uredo*, *Puccinia*, and *Æcidium* in this instance are not related, and that the *Puccinia* found on *Allium ursinum*, L., and *A. oleraceum*, L., both named *P. allii*, are also distinct from each other. They say the *Æcidium* produces, not the *Puccinia* on its own leaves, but the *Puccinia* named *P. sessilis*, Sch., peculiar to *Phalaris arundinacea*, L. The *Æcidium* is abundant in Britain, but the *Puccinia*, which should be equally abundant, or nearly so, if one parasite gives rise to the other, is here extremely rare or unknown. The *Æcidium* state of *P. allii*, Rud., is also said to be unknown, and as the *Puccinia* which commonly accompanies it is said to be foreign to it, as no doubt it is, the case must be a clear one of simple consortism. *Æcidium Berberidis*, Pers., is not the only *Æcidium* found on the *Berberidaceæ*. There is a second large-spored *Æcidium* which grows on *Berberis glauca*, D.C., in Chili, in company on the same disease spots with a *Puccinia* named *P. Berberidis*, Mont. In Europe the same *Æcidium* possibly grows on *Berberis vulgaris*, L. This fact seems to tell against the connection of the barberry *Æcidium* with the *Puccinia* of corn; but in an effort to overcome the difficulty it has been said that the spores of the Chili *Æcidium* are larger than those of the true *Æcidium Berberidis*, Pers., and chiefly on this account the Chilian parasite has been elevated to the position of a new species. Personally, we do not estimate the size of the spores in *Æcidium* as worthy of marking specific distinction. They are *extremely variable* in size in undoubted examples of *Æ. Berberidis*, Pers. A third early growing *Æcidium* also occurs on *Berberis ilicifolia*, Forst. This is named *Æcidium magelhanicum*, B., but its germ tubes are said not to enter the leaves of grasses.

If *Puccinia* and *Æcidium* are physiologically related, we have proofs that the two fungi not only arise from two different kinds of eggs which are probably both sexually produced, but the resulting fungi often cross consort with

each other, without being related, in the most complicated and bewildering manner.

In the case of *Puccinia violarum*, Link., where the *Uredo*, as well as *Æcidium violæ*, Schum., all occur on the same host, the three forms have been accepted as different conditions of one parasite; but when Mr. Vize detected a second species of *Æcidium* on white garden violas, and named it *Æ. depauperans*, a difficulty arose, for there were then two *Æcidia* and only one *Puccinia*.

We dissected and illustrated the original examples as found by Mr. Vize in the *Gardeners' Chronicle* for 16th September 1876, p. 361. Mr. W. B. Grove, M.A., has recently published a note regarding the second viola *Æcidium* in the *Journal of Botany*, vol. xxi. p. 274. In this paper the author states that he has detected the *Uredo* as well as the *Puccinia* condition of *Æcidium depauperans*, Vize, on violas; and he describes the *Puccinia* as a new species under the name of *P. ægra;* the *Æcidium* appears at the end of May and the *Puccinia* in August. Mr. Grove gives no proof that the *Puccinia* is connected with the *Æcidium;* he believes they are connected because the three forms he describes grow on the same plant. We have just shown that in several instances it is acknowledged that *Æcidium* is not always assumed to be genetically connected with a *Puccinia* when the two forms grow in company on the same plant. Mr. Grove appears not to have experimented with pro-mycelium spores.

The disparity in the number of species found under *Æcidium* and *Puccinia* is great; but the disparity is of no moment if it is acknowledged that one form can go on reproducing itself for an indefinite time without aid from the other.

Besides the *Puccinia violarum*, Lk., and *P. ægra*, Gr., there is a *P. violæ*, D.C., and a *P. violæ*, Schum.

In conclusion, one more point must be adverted to. We have shown that plants invaded by *Puccinia* and *Æcidium* carry an hereditary disease by which they are saturated,

and that the disease is capable of reaching the seeds and reappearing in the youngest seedlings. Now, if plants thus suffering from hereditary disease, and having the latent germs of disease in every part of their organisation are experimented upon in an unnatural way, have spores of fungi placed near their organs of transpiration, whose germ-threads can pierce the epidermis or enter and choke the stomata and so reach their intercellular spaces, is it not likely that this inoculating process may start into activity the latent germs of disease?

We have facts, as we think, quite comparable with this in the animal kingdom. Persons are subject to different forms of complaints, according to their constitution. Cereals are notoriously constitutionally subject to mildew; barberries are notoriously constitutionally subject to blight.

Suppose we take an instance of a person constitutionally subject to phthisis (consumption); give that person a cold and phthisis appears; but the same cold will give rise to rheumatic fever with a second constitution, and scrofula with a third, according to the tendency of the individuals to these disorders. Gout, for another example, is said to be a jealous complaint, and, with those liable to it, will always come and look in if any accident or ailment should arise. Again, the same irritating article of food will with one person produce neuralgia, with another the vesicular skin disease named shingles, with a third indigestion, with a fourth diarrhœa, with a fifth local inflammation. Vaccination in the human subject, which is comparable with spore inoculation in plants, unquestionably puts latent ailments into action. Children badly nourished will get eruptions and boils; if of scrofulous habits, abscesses or sores; if gouty or of delicate constitution, vesicular eruptions or *eczema* will often appear. The shock of an accident will also often set latent ailments into action; a blow will set the latent germs of cancer into activity. Under these circumstances we think artificial cultivation of corn in pots under bell-glasses, with fungus

spores which burst and enter by germ tubes amongst the tissues of the plants experimented upon, may possibly set the latent germs of the fungus of corn mildew into activity. In the case of the bunt of corn and of the potato disease the presence of the fungus is clearly evident to experienced observers long before the slightest trace of mycelial threads can be detected by the microscope. We cannot help thinking that more and better evidence of the supposed genetic relationship between corn mildew and barberry blight is much wanted. New illustrations are also wanted, from new and unbiassed observers, of the germinating pro-mycelium spores of *Puccinia* piercing the cuticle of the barberry. We regret that we are unable to produce an original illustration of this process of growth. A single illustration of this phenomenon has been copied, recopied, and copied again, sometimes with, but more often without, acknowledgment, that one now almost feels angry at the mere sight of the by far too familiar engraving.

All low lying lands suffer most from mildew, and it is said that elevated lands are next most seriously affected, the intermediate positions being generally most free. This fact is generally explained by the presence of mists in the low lands, and clouds on the hilltops, the mists and clouds being especially favourable to the development of *Puccinia.* Mildew is commonly seen at its worst in places where bushes and trees abound, as these objects impede free currents of air and aid fungus growth. Parasitic fungi which refuse to grow in open gardens will often germinate and produce disease at once if placed upon plants under bell-glasses. The glass aids in keeping the air damp and motionless.

We have ourselves observed corn mildew to develop with great rapidity after rain in August, and we have sometimes noticed the late sown wheat to be most affected. When the ears are badly attacked the grain is not only greatly impoverished and reduced to "skeleton grain," but it is hardly possible to separate the seed from the husks.

Mildew is said to be more frequent after crops of clover

than after other crops. We think the fact of straw from stables being so frequently thrown over old clover fields a sufficient explanation of this fact. Wheat after clover is certainly a favourite alternation of crops with many farmers,—perhaps because the old decaying clover roots act as good manure for the corn. When clover precedes corn it should be heavily folded with sheep, and straw from stables should not be used as manure.

It is now generally accepted as a fact amongst practical men that after dressing the land with farmyard manure and nitrate of soda, mildew often puts in a strong appearance; but after mineral manures, bone superphosphate, and bone meal drilled with the seed, rust and mildew are much less apparent. There can be no doubt that farmyard manure has a tendency to produce a gross soft growth in corn which is suitable for fungi, and that mineral manures, on the contrary, have a tendency to produce a firm stiff growth unsuited for rust and mildew. As corn generally does so well in dry limestone and chalky districts, a hint might be derived from this fact as to the desirability, where possible, of manuring land with chalk. We have seen this done with success in North Herts and South Bedfordshire, where chalk is easily obtainable.

It is probable that the resting-spores of the fungus of corn mildew seldom hibernate through two seasons; therefore, in instances where stable manure must be used, it should if possible be used in the crop preceding the corn or the crop following it rather than for the corn itself.

An alternation of crops is in every way desirable. Beans, peas, turnips, potatoes, clover, and other farm produce should be taken alternately with corn.

There is but one way of getting rid of corn mildew, and that is certainly not by cutting down barberry bushes and pulling up borage plants. Corn mildew is a hereditary disease, and therefore no seed corn should be gathered from mildewed plants. If the hereditary nature of the disease is disputed, it cannot be disputed that certain

examples of corn have a strong and inherited predisposition for mildew; therefore predisposed examples should be struck out and no seed gathered from them. Especial care should be taken in the rigorous selection of seed from white wheats, which are notoriously more subject to mildew than red, probably because the latter are naturally more robust. If seed merchants would guarantee that the seed corn they sell is taken solely from corn free from mildew, in the course of years the attacks and consequent losses from this pest would be considerably lessened. Mildew is every year so common in our fields simply, as we think, because the disease is planted with the grain. Old corn stubble should not be left too long in the fields. Some corn growers say that a top dressing of salt has a tendency to lessen or prevent mildew.

Mildewed straw is bad when used as food for stock in chaff, and the inferior grain is hardly fit for pigs. The straw is more commonly used as litter in stables. In this position the spores of the *Puccinia* remain uninjured, for neither warmth, frost, wet, or dryness materially affect the vitality of the resting-spores of the fungus of corn mildew. They are so small that no amount of treading from horses, herds, or flocks injures them. The warmth and dampness of the stable floor in every way suits them, and they are frequently taken from this position, full of life, and at once thrown on to the fields in the saturated straw. If the spores are consumed with food by animals, their passage through the alimentary canal does not injure them. The disease is probably, as we think, propagated by the mildewed straw being used as manure, and by the germinating resting-spores of the fungus of corn mildew infecting the first young leaves of the corn.

Mildewed straw should be destroyed, because the *Puccinia*, with its myriads of resting-spores, is in this material. We have shown that these resting-spores germinate in the spring and early summer at the exact time when rust, which is the early state of mildew, first appears. Whether

the resting-spores attack barberry bushes, or whether they do not, is of no great importance, for there are generally no barberry bushes to attack. The mildewed straw should, as far as practicable, be destroyed, and the hedges kept clear of rusted and mildewed grasses.

In taking the position here advanced in regard to the fungi of corn mildew and barberry blight, it must not be assumed that we under-estimate or disrespect the valuable published opinions of other observers. Those published opinions are, some of them, counter to ours, and we know the risk we run in appearing to question them. Still, the conclusions here given have been arrived at after many years' study, with living examples before us, and if we are not right in our opinion, we think we have advanced a sufficient number of facts to show that new and better evidence is much needed before the connection of corn mildew and the blight of barberries can be generally accepted as proved. Physiology and pathology have taught us much, but there is infinitely more to learn.

No account of the supposed connection of corn mildew with barberry blight would be complete without a notice of the essay, by Professor A. S. Oersted, published in Copenhagen, in the *Botanische Zeitung*, in 1865. This essay is intended to show that a common fungus of the Savin, named *Podisoma Juniperi-Sabinæ*, Fr., is one condition of an equally common fungus of pear leaves named *Ræstelia cancellata*, Reb. The *Podisoma* is a close ally of *Puccinia* or mildew, and the *Ræstelia* of *Æcidium* or blight. Professor Oersted says that he had learned that gardeners were of opinion that the pear fungus was never seen except after the appearance of the fungus on Savin. In contrast with this statement, if we turn to the *Mycologia Scotica* we find that the fungus of Savin is recorded from Scotland, but that the supposed secondary state belonging to pear leaves is not a Scottish fungus. Scotland is famous for its excellent gardeners, and it appears hardly possible, therefore, that any gardener can have seen in Scotland

the pear fungus following the one on Savin. Savin, like the barberry, is absent and under a general ban in many country places, owing to the improper use to which the fœtid volatile oil from the leaves has often been put as an emmenagogue; but pear leaves with the *Rœstelia* are everywhere common. The Rev. M. J. Berkeley has recorded in Hooker's *British Flora*, vol. v. part ii. p. 5, that when young pear trees are planted near old ones suffering under the *Rœstelia*, the young trees have been observed to become much injured by the fungus; and Mr. Knight sowed pear seeds in soil infested with *Rœstelia*, and the very youngest leaves of the seedlings showed the disease.

Professor A. S. Oersted carried out the usual successful infecting experiment, but in regard to it he very properly remarked: "It may very easily happen that the above experiment may be repeated many times without success, for those who are occupied in this kind of work know that a certain amount of good fortune is necessary for success."

The correctness of Professor Oersted's experiments and views were confirmed by Professor De Bary of Strasbourg in the same year, *Bot. Zeit.*, p. 222, 1865, and this confirmation tended greatly towards the general acceptance of Professor Oersted's view. Two other species of European *Rœsteliæ* allied to *R. cancellata*, Reb., were also connected with two allied European species of *Podisoma*, related to *P. Juniperi-Sabinæ*, Fr.

In the *Anniversary Memoirs of the Boston Society of Natural History*, Professor W. G. Farlow of Harvard University, a gentleman who studied with Professor De Bary, and therefore had good opportunities of seeing original experiments carried out with germinating fungus spores, has published a paper termed the *Gymnosporangia, or Cedar Apples of the United States*: Boston, 1880. In this paper Professor W. G. Farlow reviews the whole evidence for the connection of *Rœstelia* with *Podisoma* (or, as he terms it, *Gymnosporangium*) in the light of the large number of

additional species belonging to both genera as found in the United States. The author says: "There is nothing to confirm the views of Oersted as to the connection of particular species."

In reference to *Podisoma Juniperi-Sabinæ*, Fr., and *Ræstelia cancellata*, Reb., Professor Farlow points out that the former is "very common in Massachusetts, whereas its supposed *Æcidium*,—*R. cancellata*, Reb., is not known with certainty to occur at all."

Professor Farlow experimented in 1876, 1877, and 1878, with the spores of *Podisoma Juniperi-Sabinæ*, Fr., with the following results:—

Nine leaves were taken, three of *Cratægus* (hawthorn), three of *Amelanchier* (medlar), and three of apple. Spermogonia appeared on the three *Cratægus* leaves only. All nine leaves were such as the *Ræsteliæ* grow upon naturally.

An experiment was then made with a young plant of *Cratægus*. Result—nothing.

On five leaves of *Cratægus*. Result—nothing.

The first experiment was repeated with three leaves of *Pyrus* added, out of the twelve leaves spermogonia appeared on the three of *Cratægus* only, although *Pyrus* was the plant pointed out by Oersted.

Ten leaves, six *Cratægus*, three pear and one apple. Result—nothing.

Professor Farlow also records that not only did he get spermogonia on the leaves of *Cratægus tomentosa*, L., after the application of the spores from *Podisoma Juniperi-Sabinæ*, Fr.; but he got a like result from the application of the spores of *Gymnosporangium biseptum*, Ellis, and *G. macropus*, Lk., both fungi being peculiar to America, one extremely rare, and both unknown in Europe. On *Pyrus*, the genus especially pointed out by Oersted, there was invariably no result. Sometimes the spermogonia appeared suspiciously early, as in four days,—Oersted gave nine or ten,—and sometimes the *uninfected* control plants also exhibited spermogonia. Mr. Plowright mentions eighteen

days as requisite for a closely-allied species, *Gardeners' Chronicle*, 28th October 1882.

The experiments were varied in many ways, and if Professor Farlow's full reports of the carefully conducted experiments are examined, it will be seen that *heterœcism*, as regards the American species of *Podisoma* and *Rœstelia*, completely breaks down at every point. Out of nineteen experiments no less than fourteen were without result; when results followed they were contradictory, and sometimes, as Professor Farlow remarks, "desperate." In 1879 Professor Farlow was absent, but in 1880 he returned and made further experiments: these were invariably without result.

We have shown in this work that *Puccinia* (mildew) and *Æcidium* (blight) are potentially perennial, hereditary, and always either in an active or passive state in the juices of the plants invaded. Professor Farlow adverts to the same fact as regards the American fungi, and suggests that the appearance of the spermogonia was in consequence of the presence beforehand, in the leaves, of the mycelium of some *Rœstelia* which was made to develop by the moist condition in which it was placed. "I am strongly inclined," writes Professor Farlow, "to favour this view." He further states that, unless he is mistaken, he has seen the *Rœstelia* state earlier in the season than the *Podisoma;* and so, instead of following, as stated by Oersted, it has preceded, the *Podisoma.* He concludes by saying: "Another important fact is to ascertain how many of our *Rœsteliæ* are perennial. This at least appears to be the case with *R. aurantiaca*, Pk. If it should be shown that several of our *Rœsteliæ* are perennial, a fact true of our *Gymnosporangia* (*Podisoma*), and to grow in regions remote from *Juniperus* and *Cupressus,* then one could not help feeling that any connection between the two genera was probably accidental rather than genetic."

The amount of confusion that exists in books as to the host plants, and second conditions of the so-called *heterœ-*

cismal or *metœcious* fungi is now almost beyond conception. The literature is bewildering and contradictory in the highest degree. The following instance is one of the simplest; many others are involved almost beyond the power of unravelling.

In 1872 we observed an *Æcidium* invading quinces in Mr. Alfred Smee's garden at Hackbridge. At that time no such plant on quinces had been noticed as British ; but the fungus was published by us in Mr. Smee's *My Garden* under the name of *Æ. cydoniæ*, Lenz. We afterwards learned that this fungus was considered to be a mere form of *Rœstelia cornuta*, Tul., a parasite of mountain ash, and proved (?) by experiments with spores to be a second condition of *Gymnosporangium Juniperi*, Lk. Professor W. G. Farlow mentions a distinct *Rœstelia* frequent on quinces in the United States, under the name of *R. aurantiaca*, Pk., and this is probably our plant. Professor Farlow considers it a true species ; but other botanists look upon it as a variety,—not, however, of the *R. cornuta*, Tul., just mentioned, but of the totally different *R. lacerata*, Tul., whose alternate condition is said to exist in *Podisoma Juniperi*, Fr., a second parasite of *Juniperus communis*, L. In the United States, strange to say, *R. aurantiaca*, Pk., and *R. lacerata*, Tul., grow in company on the same host plants.

If the statements just given as to the quince fungus are correct, we have two confessedly very different species of fungi, both frequent on Juniper, and both able to invade quinces, and produce specifically different fungi on the leaves and fruit,—the characters of the two quince fungi being in turn so much disputed by botanists, that their names are sometimes transposed, and one made to do duty for the other ; each *Rœstelia* being supposed to answer to the characters peculiar to the other one.

Note.—On page 175 we have stated that the initial experiment of producing an *Æcidium* from germinating *Puccinia*

spores was made by Professor De Bary with *Puccinia tragopogonis*, Corda, the assumed result being *Æcidium tragopogonis*, Pers. The latter is abundant in this country, but the former, illustrated from a continental example in the left-hand figure of Fig. 90, has never yet been found in Britain. A second species of *Puccinia*, however, named *P. sparsa*, Ck., is found both in Britain and on the Continent on *Tragopogon*. This has rough or slightly echinulate spores, and is illustrated in the right-hand figure of Fig. 90. Dr. M. C. Cooke maintains the dis-

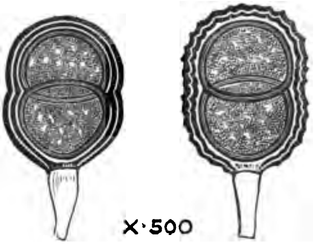


FIG. 90.
Teleutospores of *Puccinia tragopogonis*, Corda, and *P. sparsa*, Ck.
Enlarged 500 diameters.

tinctness of the two fungi, and *P. sparsa*, Ck., is retained as a species in the *Mycologia Scotica*. Many botanists, both British and Continental; look on the two parasites as quite distinct, but the advanced advocates of *heterœcism* now say they are the same, and term both *P. tragopogi*, Pers., although Persoon never gave this name.

We have not heard whether *Æcidium tragopogonis*, Pers., follows the germinating spores of *Puccinia sparsa*, Ck., on goats-beard,—if it does, and the two species of *Puccinia* are distinct, the case is similar with the one mentioned by Professor W. G. Farlow, where spermogones appeared on pear leaves after the application of the germinating spores of two species of *Gymnosporangium* and one of *Podisoma*.

CHAPTER XXVI.

NEW DISEASES OF WHEAT, BARLEY, AND RYE-GRASS, CAUSED BY

Fusisporium culmorum, hordei, and Lolii, W.Sm.

THERE can be no doubt that the injury caused to food plants by various species of *Fusisporium* is much greater than is generally supposed. We have already stated that a form of the potato disease is caused by one or more pests belonging to this genus. Perhaps one reason why some species of *Fusisporium* have been overlooked is because they are almost invisible without careful attention, combined with a knowledge of their habits of growth. Some species only resemble to the unaided eye a small gelatinous patch, and when this patch is exactly the same colour as the matrix on which it grows (which is often the case), the difficulty of detecting the fungus is increased.

A description of *Fusisporium* was given under *Fusisporium Solani*, Mart., Chapter V., one of two species found on potatoes. We will now briefly advert to three species which at present have found no place in the text-books of this country.

There is a *Fusisporium* found on wheat generally tinted with cream-colour or yellow, and possibly varying in colour from white to pink. It attacks the ears, chiefly perhaps of those plants which have been more or less invaded by corn mildew or other cereal fungi. This *Fusisporium* forms a pale yellow-orange gelatinous stratum over the ears or some portions of the ears. It glues the spikelets together and stops the growth of the grain. Although this pest has apparently been hitherto unrecognised by

botanists, we have heard of it from agriculturists at various places. The upper portion of an infected ear, as sent to us by Mr. Chas. B. Plowright from West Lynn, Norfolk, is illustrated, natural size, at Fig. 91. The dwindled portion at the apex from A to B is the part overrun by the *Fusisporium*. The fungus, owing to its orange colour, gives the ear a spurious appearance of ripeness. When the plant is magnified 400 diameters, it is seen, as at A, Fig. 92, where the crescent - shaped fusiform septate spores, so characteristic of the fungus, are illustrated. One of the spores at B is seen breaking up into four portions. After a short rest each portion will burst and produce new mycelium. A single spore is farther enlarged to 1000 diameters at C. The long cells at D belong to one of the outer glumes of the wheat spikelet. This plant may be named *Fusisporium culmorum*, W.Sm., and described as follows:—Mycelium effused, gelatinous, yellow or orange, sparingly septate, torulose; spores large, fusiform, 3·5 septate, orange. On wheat, fixing the pales, glumes, and spikelets together.

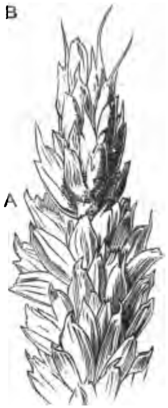


FIG. 91.—Upper part of an infected ear of wheat invaded by *Fusisporium culmorum*, W.Sm. Natural size.

Another *Fusisporium*, belonging to barley, has recently attracted attention, and this was described and illustrated with two plates in the *Jour. Roy. Micro. Soc.* for June 1883, p. 321, under, as we think, the incorrect name, as furnished by Dr. Chr. Hansen of Copenhagen, of *Fusarium graminearum*, Schwb.; this is the *F. graminum* of Corda. Unfortunately no scale of magnification was given with the plates. The author of the article, Mr. Chas. Geo. Matthews, was good enough to send us some of the infected

grains of barley, from which our illustrations were made. At Fig. 93 five of the "red corns," as maltsters term them,

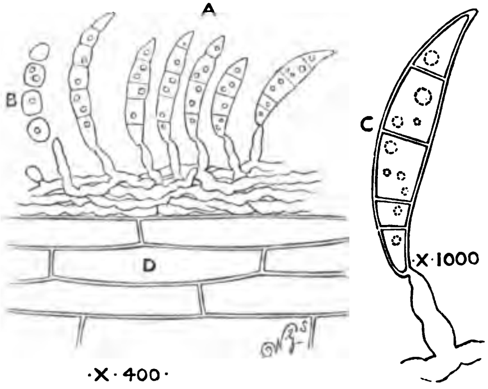


FIG. 92.
Fusisporium culmorum, W.Sm. Enlarged 400 diameters.
Spore enlarged 1000 diameters.

are illustrated twice the natural size. These misshapen "red corns" are to a great extent covered with fungus

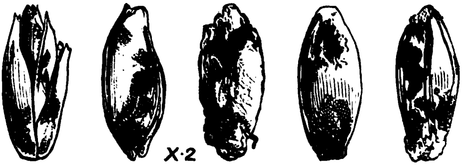


FIG. 93.
Red corns of barley, with growths of *Fusisporium hordei*, W.Sm.
Twice the size of nature.

spawn and spores, ranging in colour from pale orange to bright scarlet or deep cinnabar-crimson. The fungus itself, illustrated to the same scale as *Fusisporium culmorum*,

W.Sm., is shown at Fig. 94. It will be noticed that many of the spores have broken up, as in the last, and formed little globular spores of a second series, as at AA. These are destined to rest for a short period. Other of the spores, as at BB, are germinating whilst still attached to their supporting threads,—a common phenomenon in the genus *Fusisporium*. A single spore is enlarged to 1000 diameters at C. The cells at D belong to the flowering glume. Mr. Matthews states that the spawn of the fungus

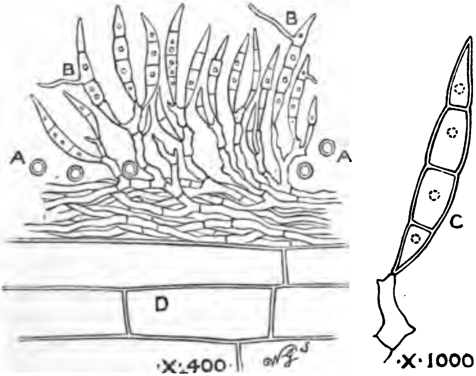


Fig. 94.
Fusisporium hordei, W.Sm. Enlarged 400 diameters.
Spore enlarged 1000 diameters.

will run over paste made of crushed germinating barley, and throw up red patches from half an inch to three-quarters of an inch high. The fungus is said chiefly to invade barley of poor quality and ill-conditioned crops and ears, seldom or never appearing on good sound barley. The germinal end of the grain is distinctly the part most seriously attacked, perhaps because it is the softest, being the spot whence the plumule and radicle of the young plant is destined to emerge. It is clear that no badly

FIG. 95.—Spike of *Lolium perenne*, L., invaded by Ergot and *Fusisporium Lolii*, W.Sm.

affected grains can possibly germinate. In both wheat and barley the fungi when present give the grain a peculiar and disagreeable taste. Mr. Matthews states that when the *Fusisporium* is introduced into sterilised beer-wort it gives rise to sluggish ferments, producing alcohol and carbonic acid gas. This species may be named *Fusisporium hordei*, W.Sm., and described as follows:—Mycelium rose-coloured or crimson; torulose, effused, forming a thick gelatinous stratum, septate; spores fusiform, acuminate at both ends, 1·3 septate, rose-coloured, crimson, or cinnabar-red. On barley, forming red gelatinous patches.

The third illustration at Fig. 95 shows, natural size, an orange-coloured *Fusisporium* on the common and valuable perennial rye-grass, *Lolium perenne*, L. The spike illustrated is ergotised, and the example illustrated was sent by Mr. Chas. B. Plowright from Norfolk. The *Fusisporium* is shown at A, B, C, and D. *Lolium perenne*, L., is unusually subject to ergot, and it is remarkable that in the spike illustrated the *Fusisporium* was invading the ergot as well as the different parts of the spikelet and seed. Young ergots are shown at E, F, and G; others are hidden by the pales and glumes. This curious species is enlarged 400 diameters at Fig. 96, a single spore being enlarged to 1000 diameters at A; the illustration at B shows the mycelium running over the

cells of the ergot. This species may be named *Fusisporium Lolii*, W.Sm., and described as follows: — Mycelium orange, torulose, effused, forming an orange gelatinous

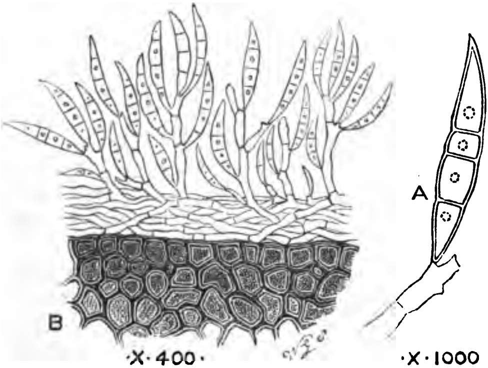


FIG. 96.
Fusisporium Lolii, W.Sm., growing on Ergot. Enlarged 400 diameters. Spore enlarged 1000 diameters.

stratum; spores fusiform, acuminate at both ends, 1·4 septate, orange. On rye-grass and its ergot. It is quite possible that some species of *Fusisporium* may be parasitic in habit. One species, *F. mucophytum*, W.Sm., grows on sound edible mushrooms; and *F. obtusum*, Ck., is described as parasitic on old fungi found under *Diatrype*, and a similar species with the last occurs in North America.

CHAPTER XXVII.

ERGOT.

Claviceps purpurea, Tul.

THE terrible effects of ergotised grass on animals that have partaken of it are so serious and so well known that a clear knowledge of the nature of ergot should be possessed by all persons interested in agriculture.

Ergot has a powerful and immediate effect, and especially so when quite fresh, in exciting muscular contraction in certain parts of animals, notably the uterus. The same contracting power of ergot is no doubt the primary cause of the well-known gangrenous diseases always popularly associated with this substance. Ergot, by contracting the muscles, stops the flow of blood to the extremities, and these extremities, unsupplied with fresh blood, sometimes rot and drop off.

The ergot produced by rye, *Secale cereale*, L., is one of the largest, best known, and probably the most potent, and this is the substance invariably used in medicine. Ergot is commonly termed ergot of rye, but the fungus growth is very common on other cereals and on many grasses. Amongst others it has been recorded in Britain as parasitic upon the following plants :—Mat grass, *Nardus stricta*, L.; catstail-grass, *Phleum pratense*, L.; foxtail grass, *Alopecurus pratensis*, L.; reed canary-grass, *Phalaris arundinacea*, L.; vernal grass, *Anthoxanthum odoratum*, L.; waved hair-grass, *Aira flexuosa*, L.; turfy hair-grass, *Aira cæspitosa*, L.; oat-grass, *Arrhenatherum avenaceum*, Beauv.; meadow soft-grass, *Holcus lanatus*, L.; creeping soft-grass, *Holcus mollis*, L.; cocksfoot grass, *Dactylis glomerata*, L.; smooth meadow-

grass, *Poa annua*, L.; floating sweet-grass, *Glyceria fluitans*, R.Br.; tall fescue-grass, *Festuca elatior*, L.; meadow fescue-grass, *Festuca pratensis*, Huds.; wheat, *Triticum sativum*, L.; wheat-grass, *T. repens*, L.; rye-grass, *Lolium perenne*, L.; darnel-grass, *Lolium temulentum*, L.; lyme-grass, *Elymus arenarius*, L.; rye, *Secale cereale*, Welld.; barley, *Hordeum distichum*, L., on species of *Agrostis*, and no doubt on many other grasses, including rice, *Oryza sativa*, L. A large North American species of lyme-grass, sometimes seen in our gardens under the name of *Elymus giganteus*, Vahl., produces a very large ergot.

In describing ergot we will take a spike of ergotised rye, and after examining one of the ergots which it has produced, we will follow up the life-history of the fungus and show how it produces other ergots like itself. We will then glance at the effects of ergot on man and other animals, and see how the attacks of ergot on grasses may be lessened or prevented.

If we take a spike of ergotised rye—*Secale cereale*, L., as illustrated, natural size, at Fig. 97—we see one or more of the rye seeds replaced by blackish hornlike

* FIG. 97.—Spike of ergotised Rye, *Secale cereale*, L. Natural size.

growths, as at A, B, C, D, twice or three times as long and stout as the normal rye seeds. In old times the ergot was supposed to be an unusually large and diseased rye grain. If it grew on wheat it was considered a somewhat large grain of wheat, just as the galls known under ear-cockle were at one time supposed to be unusually small and cockled seeds. If we remove an ergot from a spike we shall see

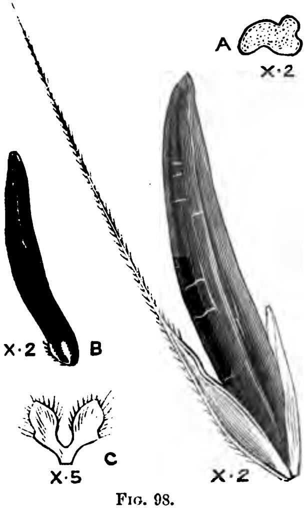


FIG. 98.
Ergots of Rye, and section. Twice the size of nature.
Lodicule of Rye. Enlarged 5 diameters.

that its production has not materially injured the spike of grain, and that its growth has been confined to the spikelet from which it was taken. On looking at ergots with a lens we see them, enlarged to twice their natural size, as at Fig. 98. We notice that they are longitudinally corrugated and minutely granular, often slightly split both transversely and longitudinally, the cracks often showing

a reddish margin, and exposing the whitish interior substance of the ergot. A transverse section through an ergot is shown at A. Sometimes the minute scales or lodicules remain attached to the ergot, as at B. These latter organs are farther enlarged to five diameters at C, so that they may be compared with the smaller lodicules of wheat enlarged to the same scale at Fig. 42. See also Fig. 43. There is a faint sickly odour of camphor attached to fresh ergot, and if we hold it in a flame it immediately takes fire and burns like the kernel of a nut, constantly giving off little jets of flame, and dispelling a not unpleasing odour. The ergot burns thus freely because it contains a brownish-yellow, viscid, aromatic, slightly acrid, oil. Its taste when raw is slightly bitter and nauseous. If we now cut an ergot in two, either transversely or longitudinally, and then remove an extremely thin transparent fragment from the exposed surface and magnify 400 diameters, we shall see the structure as at Fig. 99. We now observe a densely-compacted mass of cells with thick pale-brown walls, many of them made polyhedral by the pressure of adjoining cells. A few cells are elongated, and appear to wind between the globular and polygonal cells in a sinuous fashion. If the ergot is sliced in any part, the same appearance presents itself—densely-packed thick-walled cells filled with a viscid oily liquid.

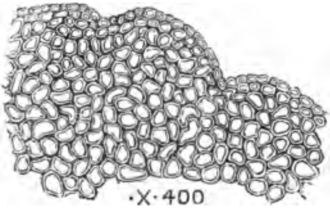


FIG. 99.—Transparent slice of Ergot. Enlarged 400 diameters.

After this examination we clearly see that we are not dealing with a perfect fungus, but with a *Sclerotium* not dissimilar from the one found on potatoes, and illustrated to the same scales with ergot in Figs. 4 and 5. In colour, size, and general appearance, the *Sclerotia* of

potatoes and the ergot of rye are so much alike that if a large number were mixed together it might be no easy task to distinguish in every instance one from the other. Ergot is described in old botanical books as *Sclerotium clavus*, D.C., or *Spermœdia clavus*, Fr.

If we keep ergots all through the winter on moist sand on a garden bed, or indoors, they will germinate in the early summer precisely in the same way as the *Sclerotia* of potatoes already described; and although the ergots will not produce a *Peziza* as the potato *Sclerotia* did, yet they will give rise to a fungus of equal if not of greater interest.

If ergots are laid in a clean, moist, shady place in a garden, they will germinate naturally in June; or if a search is made where dead ergotised rye or other ergotised grasses have lain, the germinated ergots will sometimes be found without difficulty.

Just as different grasses vary a little in their time of flowering, so ergots vary in their time of germination. An early flowering grass is invaded by an early germinating ergot, and a late grass by a late ergot. Grasses and ergots alike flower and germinate at a somewhat different period in the south of England and the north of Scotland. Surrounding circumstances have modified the habits of both grass and fungus. The range of time in the flowering of grasses and germinating of ergots is included in about three months.

If we now take a germinated ergot such as either of the two illustrated, twice the natural size, at Fig. 98, and examine it, we shall see that it has produced several club-shaped growths, curiously answering in appearance to, although considerably smaller in size than, the *Peziza* with the slender tortuous stem produced by the potato *Sclerotium*, as illustrated, natural size, at Fig. 6. Like the potato *Peziza* the growths from ergot have a somewhat long tortuous stem and a cap, as illustrated the natural size, at Fig. 100, and here the similarity ends. Each little

white-stemmed fungus which grows from a white downy base out of ergot in the summer is furnished with a small spherical head of a beautiful pale purplish colour. This growth, enlarged five diameters at A, Fig. 101, was at one time supposed to be a parasite on ergot, but it is now known to be the perfect condition of the ergot itself. The *Claviceps* derives its nourishment from the ergot, and after the *Claviceps* has appeared

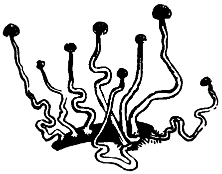


FIG. 100.--Ergots germinating and producing *Claviceps purpurea*, Tul. Natural size.

the ergot collapses and perishes ater the manner of the seed tuber of a potato plant. Tulasne has named this perfect state of ergot *Claviceps purpurea.* *Claviceps* of

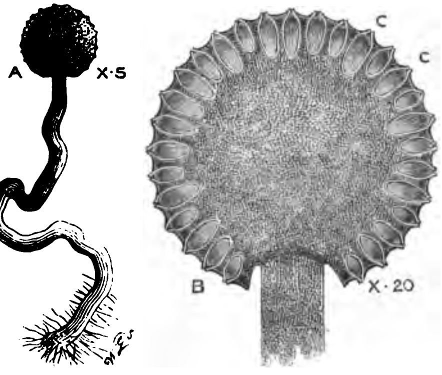


FIG. 101.
Claviceps purpurea, Enlarged 5 diameters; and section through head or stroma. Enlarged 20 diameters.

course refers to the clublike head, and *purpurea* to its beautiful purplish colour. The popular name "Ergot" is French for the spur of certain birds.

Our attention must now be directed to one of the pale

purple globose heads. Externally they are irregularly dotted over with little prominences, as at Fig. 101, A, enlarged five diameters ; and in this they greatly resemble the clubs belonging to *Torrubia* found growing upon a buried truffle (see Fig. 22). On cutting longitudinally through the head of the *Claviceps* of ergot we find it like the parasitic growths belonging to the truffle (and unlike the potato *Peziza* illustrated at Fig. 7). We see it, if enlarged twenty diameters, as at B, Fig. 101, packed all round its outer surface with small flasks, conceptacles, or *perithecia*, with the mouths of the flasks all opening towards the outside. The little projecting mouths, as at CC, represent the minute prominences seen on the outside of the cap or *stroma* at A. As with the former fungi we have described, we must now cut an extremely thin transparent slice off the exposed cut surface of the head, and magnify with the highest powers of the microscope to make out the nature of one of the minute conceptacles or perithecia and its contents.

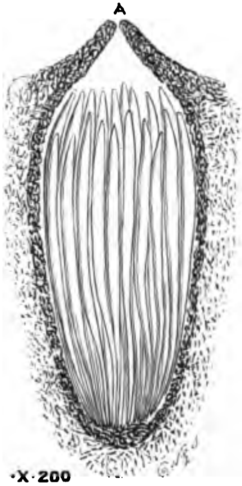


FIG. 102. -Section through a conceptacle or perithecium of *Claviceps purpurea*, Tul. Enlarged 200 diameters.

If we magnify a single perithecium or conceptacle 200 diameters, we shall see it as at Fig. 102. We now notice, as in former examples, that the flasks, conceptacles, or perithecia are closely packed with fine long transparent bladders, which spring from the base of the perithecium. The mouth from which these bladders ultimately emerge

is at A. By dexterously moving the cover-glass, or by manipulating with a needle, we may easily get some of these contained asci or bladders free from the flask, and when free a single ascus will be seen if magnified 500 diameters, as at A, Fig. 103. We now perceive that they are not empty bladders, for through their transparent walls we can see that each contains eight extremely fine long attenuated bodies, which are sporidia or spores. One of these spores from an ascus is farther enlarged to 1000 diameters at B. If reference is now made to the ascus and sporidia belonging to the potato *Peziza*, as illustrated to the same scale at Fig. 9, the difference, especially in the spores, will be seen; and if the sporidium of the *Torrubia* of the truffle is turned to at H, Fig. 22, a similar long attenuated body will be seen. The sporidium from the *Torrubia* is furnished with an enormous number of joints, whereas it will be noticed that the body now before us is apparently in one piece. The exceedingly small, long, needle-like, extremely attenuated sporidia belonging to germinated ergot are produced in June. When we have an ergot with the club-shaped *Claviceps* upon it we have the ergot in fruit.

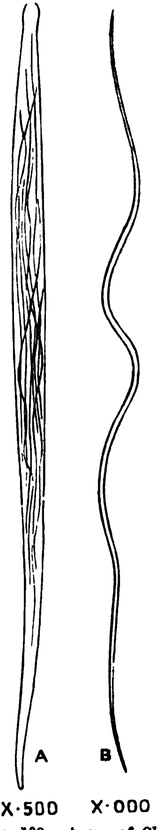


FIG. 103.—Ascus of *Claviceps purpurea*, Tul. Enlarged 500 diameters. Sporidium of *ditto*, enlarged 1000 diameters.

On a June day, then, we have a fruiting ergot before

us, and the problem presents itself for solution—How do these inconceivably minute hairlike bodies or sporidia free themselves from the asci and perithecia of the *Claviceps*, and cause ergot in grasses?

If germinated ergots are kept in moist air under a bell glass and observed against a black background in sunshine, the ejection of the spores like shining needles or almost invisible glittering arrows may be clearly seen with a lens. What power it is that causes the discharge from the flasks no one has at present certainly explained; but the phenomenon is well known to occur in many fungi. The discharge takes place after a sudden touch or movement, or on a change of light or temperature, as when a sunbeam suddenly falls on any ascus-bearing fungus. The glittering hairlike spores are shot from the mouths of the perithecia into the air radially in all directions. The sporidia may be easily caught and examined if strips of glass are smeared slightly with glycerine and placed under a bell glass near the ripe fungi. The sporidia can then be examined whilst alive and fresh. The asci as well as the free sporidia are often expelled, and it frequently happens that the act of expulsion is too weak to propel the sporidia or asci into the air, and they hang only half expelled from the mouths of the perithecia.

If we now suppose ourselves to be in a district where rye is common, and where rye was ergotised during the previous autumn, we shall have the rye in flower at the precise time when these myriads of glittering little needle-like sporidia are sailing through the air. Such needle-like spores as do not light upon flowering grasses perish; but where there are so many millions of sailing spores some must of necessity fall upon the flowers of a grass—let us say rye.

We must now imagine a needle-like sporidium falling close to the pistil and stamens, and reaching the base of the pistil of a flower of rye. Here the spore bursts or germi-

nates, and in bursting forms a microscopic drop of glittering vital material. This glittering viscid drop at the base of the pistil speedily increases in size, and after about three days it becomes visible to the unassisted eye. Its increase in size is probably aided by an exudation from the rye spike itself near the base of the pistil, and by absorption of moisture from the atmosphere. The glittering liquid has a great attraction for various flies, and no doubt insects aid in the propagation of ergot. The liquid, however, appears to kill some flies; for our friend Mr. A. S. Wilson has made the curious observation that he has seen hundreds of flies standing on newly-ergotised grasses in the stillness of death. On examination of this viscid drop with the microscope, we see it traversed by a transparent filamentous sweet-tasting mycelium, the beginning of ergot. The mycelium attaches itself to the base of the pistil, and partly covers the ovary; it partially penetrates the tissues of the pistil, generally leaving the upper part exempt. The mycelium now occupies the place of the pistil which it soon pushes from its place, and as the fungus enlarges in size it becomes deeply furrowed and honeycombed, and often carries the feathery styles on its apex, and so somewhat resembles an aborted grain of rye. As the viscid mycelium continues to grow, its base becomes compact and indurated, and this indurated base, anatomically connected with the viscid matter above, is the beginning of true ergot. A half-grown ergot is illustrated at Fig. 104, enlarged five diameters, with the true ergot at the base, A, and the viscid matter at the top, B. The apex at C is crowned with the withered styles which have been forced from their natural position. At D a longitudinal section through this young ergot and its glutinous top is illustrated.

In old times the early viscid condition of ergot, coating and pushing up the aborted seed was considered to be a distinct fungus, and, like the *Claviceps* of germinating ergot, was considered a parasite of ergot. The glutinous

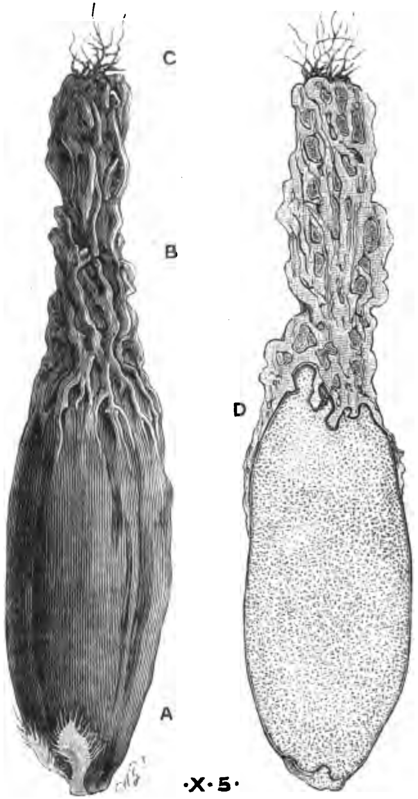


FIG. 104.
Half-grown Ergot and section. Enlarged 5 diameters.

condition of ergot is generally described under the name of *Sphacelia*, a word derived from the Greek, and meaning gangrene. The same word in a secondary sense means

mildew. We have the English word sphacelate, which means to become affected with gangrene.

It unfortunately happens that this viscid early condition of ergot has had other names in addition to *Sphacelia.* Queckett termed it *Ergotœtia abortifaciens*, whilst Messrs. Berkeley and Broome believed it to be an *Oidium*, and described it as *O. abortifaciens;* and in this they were perfectly justified, for the fungus displays the characters of a true *Oidium*, a condition of some fungi which has been adverted to before in this work under the *Oidium* of the turnip, and the *Oidium* or early condition of the *Erysiphe* of grass mildew. The *Sphacelia* is the *Oidium* or larval state of ergot.

FIG. 105.—Section through the *Sphacelia* or *Oidium* of Ergot. Enlarged 400 diameters.

We must now once more return to the microscope, and take a thin, transparent slice from the point of junction between the indurated ergot below and its viscid *Oidium* top. If we magnify a thin sectional slice 400 diameters, we shall see it as at Fig. 105: the compacted cells of the ergot are at the bottom left-hand corner, and the much looser mucilaginous and filamentous growth is shown above. The upper part is the *Oidium* or *Sphacelia*, which not only carries its own nucleated conidia, but is often swarming with *bacteria* and minute infusiorial

animals. We now see that the walls between the furrows consist of elongated *Oidium*-like cells springing from a gelatinous substratum, and each cell supports an *Oidium* spore or *conidium*. These little spores or sporidia germinate very readily in water or on any moist surface, and by this means they not only continually increase the *Oidium* growth, but they can, on being blown on to grass flowers, cause the production of other viscid early states of ergot. It will be remembered that *Oidium Balsamii*, Mont., reproduces itself in the same manner on turnips; *O. monilioides*, Lk., does so on grasses, and *O. Tuckeri*, B., on the vine. A conidium or stylospore germinating at A, and producing another stylospore exactly like itself at B, is shown at Fig. 106, enlarged 1000 diameters. As the true compacted ergot below increases to its full size, the less compact *Oidium* growth above collapses and falls away. The true ergot is then left devoid of its viscid, watery apex, with its little tortuous furrows and conidia or stylospores in the condition in which we first began our observations upon it.

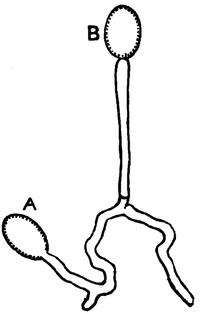


FIG. 106.—Spore of *Sphacelia* or *Oidium* of Ergot, germinating at A, and producing a spore or *conidium* at B. Enlarged 1000 diameters.

The value of the *Oidium* growth to the ergot is obvious, for if one needle-shaped spore from a *Claviceps* produces the infant state of ergot on one rye-flower, we see that in a few days this larval condition can produce thousands of new *Oidium* spores, each spore being equally powerful with a *Claviceps* spore in producing ergot. Ergots seldom germinate and produce the *Claviceps* when more than a year old; two-year old examples have, however, been known to sprout, but we have not heard of three-year old specimens germinating. In concluding this subject we will mention

some of the effects of this pest, and say how its general prevalence may be reduced.

The consumption of ergot when it is ground up with grain causes chronic dry, black, or livid gangrene, sometimes with but little fever, inflammation, or pain. The limbs affected become insensible and cold, and, in the progress of the disorder, dry, hard, black, and withered. In some instances violent pain has been recorded, with redness, insupportable heat, and delirium. A line of separation, reaching to the bone, is formed by the disease between the dead and living tissues. Ergot is especially potent, when taken fresh and raw, in exciting strong uterine contractions; and when a small portion only is consumed, it causes weaker contractions which wear out the injured animal with fatigue. A correspondent of the *Gardeners' Chronicle*, 1st June 1876, states that he has observed cows lose their calves prematurely at the time ergot appears. It is curious that, when ergot is ground with grain and cooked in bread, abortion or premature birth is not the usual result. It has been computed that in wet seasons, in some parts of France, one-fourth of the rye used for bread consists of ergot; the poor, it appears, taking no pains to separate the ergots, and the result of its consumption is often some form of ergotism. M. Duchamel mentions, in the *Memoirs of the Royal Academy* for 1748, that out of 120 persons attacked scarcely four or five escaped with their lives.

In the *Philosophical Transactions* (1763) vol. lii., part ii., for the year 1762, p. 526, is a printed extract from a letter from the Rev. James Bones, M.A., of Wattisham, near Stowmarket, Suffolk, to George Baker, M.D., F.R.S., relating to a case of mortification of limbs in a family there.

The letter says that on Sunday, 10th January, Mary, daughter of John and Mary Downing, sixteen years old, felt a violent pain in her left leg, which, in an hour or two, also affected her foot, and particularly her toes. On the next day her toes were much swollen, and black

spots appeared on them. By degrees the whole foot became swollen and black. The pain, which was now chiefly in her toes, was, as she said, as if dogs were gnawing her. The blackness and swelling advanced upwards by slow degrees, till they reached the knee, where the flesh broke, and a great discharge followed. In a little time the flesh of her leg putrified and came off at the ankle, together with the whole foot, leaving the leg-bones bare. Her other foot and leg were affected in a few days, and decayed, nearly by the same degrees and in the same manner. She had then an abscess formed in one of her thighs. In a subsequent note it is stated that this girl, who had sat for fourteen weeks in a chair, and for seven days without any feet, or flesh on her leg-bones, had at length consented to have the bones taken off.

Mary, the mother, was seized within a few hours of her daughter's first seizure with the same violent pain under her left foot, or, as she sometimes said, in her left leg. Her toes, foot, and leg were affected in the same manner as her daughter's; and in a few days her other leg and foot suffered in like manner. The flesh of one leg had separated, and come off at the knee, leaving the bones bare, which she would not suffer to be taken off. The other foot had rotted off at the ankle. Her hands and part of her arms were, from the first attack, without sensation, and her fingers contracted. In a subsequent letter it is stated that the mother "still remains in bed with her leg-bones bare, which she will not suffer to be taken off."

In four or five days after the eldest daughter and the mother were first affected, Elizabeth, aged fourteen years, Sarah, aged ten, Robert, aged six, and Edward, aged four, were all taken on the same day with violent pains in the feet and legs, chiefly in the left.

Elizabeth was seized only in one leg and foot, which, during three weeks, she could not set on the ground, but stood all the time on the other foot, leaning against the

chimney; after which, being taken in the same manner in the other foot, she was obliged to lie down. One foot mortified and came off at the ankle, and the other leg near the knee.

Sarah was taken in one foot, which mortified and came off at the ankle. The other leg suffered in the same manner, and also separated at the knee.

Robert was taken in both feet. His legs separated at the knees. . . . Edward was taken in both feet, which separated at the ankle . . . etc.

The report then describes the death of an infant, whose hands and feet turned black after death, and the illness of the father, whose fingers were benumbed, contracted, and black, the nails coming off, and two of the fingers becoming ulcerated. Then follows a description of the persons afflicted and their food, but no hint is given as to the presence of ergot.

In the subsequent letter, before referred to, it states at page 530 that the family had no rye, but had been "used to buy two bushels of *clog-wheat*, or *revets*, or *bearded wheat* . . . every fortnight. Of this they made their household bread." The wheat, it appears, had been *laid*, and was thrashed separately lest it should spoil the *samples*. It was not mildewed or grown, but discoloured and smaller than the other. It made bad bread and worse puddings. A labouring man who used the bread was affected with a numbness of both his hands for about four weeks. His hands were continually cold, and his finger ends peeled. One thumb was at the time of the report still without any sensation.

A note at the end of the second letter says "there is, in *L'Histoire de l'Académie Royale des Sciences*, for the year 1710, a paper, the title of which is *Sur le bled cornu appellé Ergot* (*Secale corniculatum nigrum*, mentioned as a poison by Hoffmann)." Here it is said that M. Noël, surgeon of the Hôtel-Dieu at Orleans, within about a year's time had received into the hospital more than fifty

patients afflicted *d'une gangrene sèche, noire et livide*, which began at the toes and advanced more or less, being sometimes continued even to the thighs. He adds "he observed that this disease affected the men only; and that, in general, the females, except some very young girls, were free from it."

In the same paper is mentioned, as a fact well known to the Academy, the case of a peasant who lived near Blois. In this patient a gangrene, at its first attack, destroyed all the toes of one foot, then those of the other, afterwards the remaining parts of both feet; then the flesh of both his legs and that of his thighs rotted off successively, and left nothing but bare bones.

The members of the Academy were of opinion that the disease (of which M. Noël had sent an account) was produced by bad nourishment, particularly by bread in which there was a great quantity of ergot. This substance is described by M. Fagon, first physician to the king, and is said by him to be a "kind of monster in vegetation, which a particular kind of rye sown in March is more apt to produce than what is sown in the autumn, and which often abounds in moist, cold countries and in wet seasons."

Professor J. S. Henslow, in commenting on the Mattishall case, in the *Journal of the Royal Agricultural Society of England*, vol. ii., 1841, says there was no evidence that the presence of ergot was suspected in the wheat used, and although ergot is supposed seldom to attack wheat, yet Professor Henslow says that he had found it in 1841 in four different fields of wheat, and gathered more than a dozen specimens. Some of the Suffolk farmers were sufficiently acquainted with it to satisfy Professor Henslow that ergot was more common on wheat than was at that time commonly suspected. Upon asking his miller to search, he soon picked out about three dozen ergots from two bushels of revet wheat which had been sent to be ground at his mill, and he said that he had left at least as many more in the sample. This wheat was

grown in the next parish to Wattisham. A very cursory look into a sack of gleaned wheat then at the mill also furnished Professor Henslow with three or four more specimens.

From our own experience we should say that ergot in wheat is by no means uncommon, as we have generally found it on searching. Our examples have always been much smaller than the ergot of rye, and not much larger than a grain of wheat.

Our friend the Rev. Canon Du Port, M.A., of Mattishall, Suffolk, writing in the *Transactions of the Norfolk and Norwich Naturalists' Society*, vol. iii. p. 199, says a considerable quantity of ergot was found among the marshland wheats in the year 1879, in which the summer was abnormally wet and sunless.

It unfortunately happens that ergot is extremely frequent on the common rye grass, *Lolium perenne*, L., a valuable grass, never absent from pasture-land and always present in permanent pastures. Professor Henry Tanner states, in the *Journal of the Royal Agricultural Society of England*, No. xli., 1858, that he knew of a Shropshire breeder who lost £1200 in three years from the prevalence of ergot in his fields. Ergotised grass is especially damaging to animals at the time when the uterus is nearly ready to exclude its contents.

In some instances it is easy to sift ergot out of grain, as the ergots are larger in size than the seeds; but in other instances, as in wheat, the ergots are often so similar in size with the grain that hand picking is the only means that can be used. As ergots are generally black, there is no special difficulty in recognising them amongst seeds.

It is said that ergot is most abundant in ill-drained positions, and that good draining materially lessens it. When the grasses of pastures are ergotised it is well to pass a sharp scythe over the top of the grass and remove as far as possible the spikes, racemes, or panicles; and

this material, which is a common cause of abortion, should be raked together and placed out of the reach of the flocks and herds. In districts notoriously subject to ergot the scythe may be used in a similar manner at the flowering time of grasses, for as the spores of the *Claviceps* attack the young flowers, it is obvious that the ergots will be many or few according to the number of grass flowers.

CHAPTER XXVIII.

WILSON'S VARIETY OF CLAVICEPS ON ERGOT.

Claviceps purpurea, Tul., var. *Wilsoni*, W.Sm.

No account of ergot would be complete without a description of a curious form of the germinating ergot of floating sweet grass, *Glyceria fluitans*, R.Br., observed by our friend Mr. A. Stephen Wilson near Aberdeen.

Glyceria fluitans, R.Br., is common in wet and muddy places and in stagnant pools and slow-running streams; and, in our opinion, the peculiar variety of *Claviceps* named *Wilsoni* entirely owes its origin to its peculiar environment, so different as it is from the environment of wheat, rye, and other cereals, and many grasses. Mr. A. S. Wilson, in July last, obligingly forwarded us a considerable number of germinated ergots of *Glyceria fluitans*, R.Br., on which the new and curious variety of *Claviceps* was growing, and from these examples the following notes and illustrations have been prepared.

Mr. Wilson detected these growths in July 1882 after a very wet spring and early summer. In July 1883 they were less common, and were intermixed with the normal purple form of the *Claviceps* described in Chapter XXVII. Sometimes the purple form as well as the new white or yellowish one was growing from the same ergot.

Four germinated ergots carrying *Claviceps purpurea*, Tul., var. *Wilsoni*, W.Sm., are engraved, natural size, at Fig. 107. This illustration may be compared with Fig. 100, where the normal form is illustrated, natural size.

Two germinated ergots are enlarged five diameters at Fig. 108, for comparison with Fig. 101, A, where the

normal form is similarly enlarged. The variety differs from the typical form in being whitish or yellowish instead of pale purple in colour, and in the perithecia or

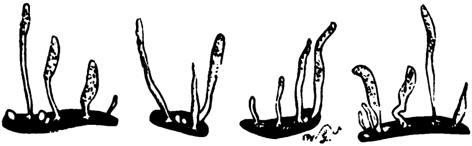


FIG. 107.
Claviceps purpurea, Tul., var. *Wilsoni*, W.Sm., growing from Ergot
Natural size.

conceptacles being almost free on an elongated clublike growth instead of being immersed in a globular head or *stroma*. Many of the growths of the variety *Wilsoni*,

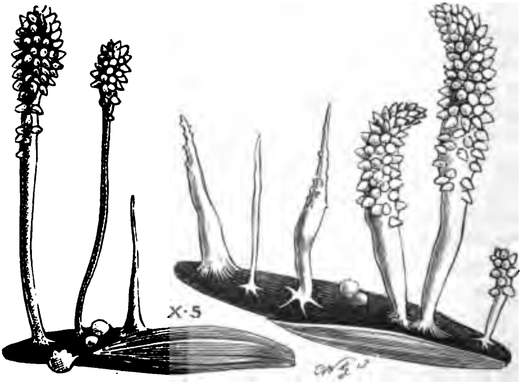


FIG. 108.
Claviceps purpurea, Tul., var. *Wilsoni*, W.Sm., growing from Ergot.
Enlarged 5 diameters.

W.Sm., are hair-like, others are attenuated upwards from a thicker base and bear no perithecia. The whole growth is less firm than the type, and instantly reminds one of an ab-

normal variety. The *Claviceps* grows from the interior of the ergot, and bursts through cracks on the surface. Sometimes the crack or opening is very small, and through this small opening the *Claviceps* emerges and speedily produces a matted base of mycelium upon the surface of the ergot, before the club is produced. In some instances the base of spawn is so thick that the *Claviceps* superficially resembles a parasite upon ergot rather than a true fruiting condition of ergot itself. Sometimes this effused mycelium spreads over the ergot, and several clubs arise from one stratum of mycelium, which may have emerged from one minute hole or crack in the black ergot or *Sclerotium*. The pales of the grass flower are shown attached to the ergots in Fig. 108.

FIG. 109.—Upper part of *Claviceps purpurea*, Tul., var. *Wilsoni*, W.Sm. Enlarged 20 diameters.

The upper part of a club is illustrated at Fig. 109, enlarged twenty diameters, for comparison with the normal club of *Claviceps purpurea*, Tul., illustrated to the same scale at Fig. 101, B. It will now be noticed that the perithecia or conceptacles are, on the average, the same in size and character in both fungi, the only difference being that the club is drawn up in the variety *Wilsoni*, W.Sm., and its soft substance is drawn away from the perithecia, which are left almost free instead of being embedded as in the typical *C. purpurea*, Tul. A phenomenon of this class is one of the commonest in the vegetable kingdom, and is especially

frequent in the inflorescences of flowering plants. The growth is comparable with an umbel lengthening into a raceme or corymb. Such abnormal growths are especially common in wallflowers (*Cheiranthus*) and candytuft (*Iberis*).

A single conceptacle is shown, enlarged 200 diameters, at Fig. 110, for comparison with the normal conceptacle illustrated to the same scale at Fig. 102. There is a little difference in the form, but virtually the two growths are the same in both fungi. Tulasne has illustrated the normal form of *C. purpurea*, Tul., precisely like our Fig. 110. The conceptacle is packed with asci or bladders containing sporidia.

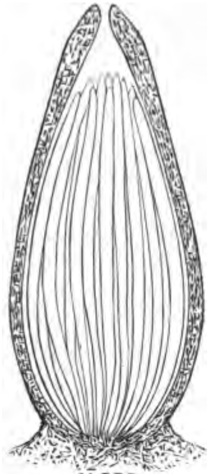


FIG. 110. — Conceptacle of *Claviceps purpurea*, Tul., var. *Wilsoni*, W.Sm. Enlarged 200 diameters.

A single ascus removed from a conceptacle, with its contained sporidia, is illustrated at Fig. 111, A, enlarged 500 diameters; and a single sporidium, enlarged to 1000 diameters, at B, for comparison with the same parts engraved to the same scale from the normal growth in Fig. 103. A slight difference in size may be noted; but this ascus and sporidium were taken from the largest and most mature conceptacle we could find—others were not half the size. Average specimens are exactly the same in size and form in both fungi.

The ergots from which the variety *Wilsoni* grew were from the bottom and shady side of a half-dry Aberdeenshire ditch. In this position they were found naturally covered with decaying grass. To us the ergots appeared much less firm than the ergots from rye, and in some instances they

were diseased and covered with a remarkable *Saprolegnia*, with distinctly septate mycelium, not unlike Fig. 24 in this work. To our mind every fact points to the conclusion that the variety *Wilsoni*, W.Sm., owes its peculiar conformation to the wet and shady position in which it grows.

We have been particular in the description and illustration of this variety, as our friends Messrs. Plowright and Wilson have described this form under another generic name in the *Gardeners' Chronicle* for 9th February 1884. It is there described and illustrated as a *parasite* of ergot under the name of *Barya aurantiaca*, P. and Wils. The authors state that they have been unable to make the sporidia reproduce ergot in wheat, rye, and *Poa trivialis*, L.; but this fact need not cause special surprise, if the whole growth is regarded, as we regard it, as a mere monstrous and abnormal form; besides, the experiments should have been made with *Glyceria fluitans*, R.Br., whence the ergots were derived, and not with wheat, rye, and *Poa trivialis*, L. Mr. Wilson originally considered the new variety to be a mere degraded condition of *Claviceps purpurea*, Tul., and in this original determination we consider he was correct.

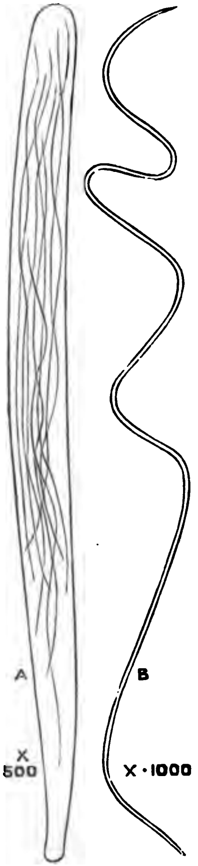


FIG. 111. — *Claviceps purpurea*, Tul., var. *Wilsoni*, W.Sm. *Ascus* enlarged 500 diameters; *Sporidium* enlarged 1000 diameters.

Dr. M. C. Cooke, M.A., in *Grevellia*, vol. xii., March 1884, p. 77, has, since the above notes were written, described *Barya aurantiaca*, P. and Wils., as a species under the name of *Claviceps Wilsoni*, Cke. He says it differs from all other species of *Claviceps* in the elongated clavate capitulum and in the lax manner in which the conceptacles or perithecia are immersed. We do not, however, esteem this form to be worthy of specific rank.

We consider also that the *Claviceps microcephala*, Tul., on reeds is not a species but a mere variety of *C. purpurea*, Tul. One is connected with the other by a continuous series of intermediate forms, and the typical form of *C. purpurea*, Tul., sometimes occurs on the ergots of reeds. If these two fungi should ultimately prove to be distinct, hybrids undoubtedly occur, which probably arise from the spores belonging to the two different forms of *Claviceps* lighting on a single grass flower, and there bursting and producing a hybrid *Sphacelia*, which is the beginning of ergot. Or if the spores of the *Oidium* state of *Claviceps purpurea*, Tul., and *C. microcephala*, Tul., were blown on to the same grass flower, the watery contents of the burst spores or conidia would conjoin and form a hybrid *Sphacelia*.

CHAPTER XXIX.

MILDEW OF PARSNIPS.

Peronospora nivea, Ung.

THE descriptions we have already given of *Peronospora trifoliorum,* D.By., *P. exigua,* W.Sm., *P. Schleideniana,* Ung., and *P. parasitica,* Pers., more or less hold good with the present species, which is often described under the name of *P. umbelliferarum,* Casp. *Peronospora nivea,* Ung., affects various umbelliferous plants, but is especially formidable in its attacks on our garden parsnips. The fungus lives within the tissues of the invaded plants, and attaches itself to their constituent cells by minute suckers growing from its somewhat torulose mycelium. Like other species of *Peronospora* it causes putrescence in the plants it attacks, and sets up decay in the leaves, stems, and roots. This is very noticeable in the root of the garden parsnip. As with the fungus of the potato disease, the mycelium often descends the stem by the interior. In the parsnip the large fleshy esculent tap roots become spotted and at length putrid in a way similar with diseased potatoes.

The parasite is very common on the Cow parsnip, or hogweed, *Heracleum Spondylium,* L.; the wild Angelica, *Angelica sylvestris,* L.; and the Goutweed or Bishopweed, *Ægopodium Podagraria,* L.

The general appearance of this fungus is shown in Fig. 112, where a single fruiting-stem or conidiophore is enlarged 400 diameters. The spores or conidia, as may be seen, are supported on threads or spicules of extreme tenuity. The point of junction between the parsnip leaf and the fruiting branch of the *Peronospora* is shown at E.

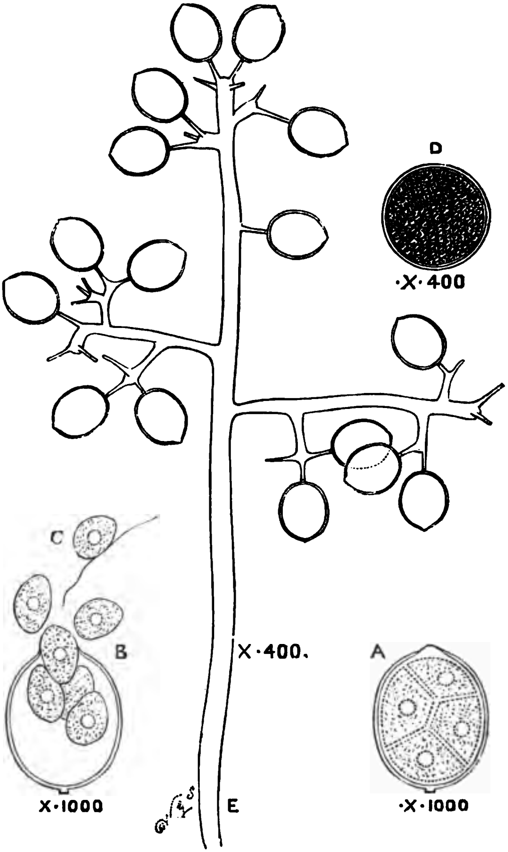


FIG. 112.—MILDEW OF PARSNIPS.
Peronospora nivea, Ung., enlarged 400 diameters; conidia and zoospores, enlarged 1000 diameters; oospore or resting-spore, enlarged 400 diameters.

At this point the fungus emerges through one of the organs of transpiration as shown in *Peronospora trifoliorum*, D.By., Fig. 1; *P. parasitica*, Fig. 29; and *P. infestans*, Mont., Fig. 127. A single conidium or spore is farther enlarged to 1000 diameters at A. As maturity is reached the vital material within the dull-coloured, non-lustrous, spores, divides or differentiates itself into several polyhedric portions, and each of these portions ultimately bursts out of the conidium as at B. Soon after emergence these little spores become furnished with two extremely fine and attenuated vibrating hairs or cilia as at C; and with these cilia the spores are able to propel themselves and sail about with some rapidity over any moist surface. These zoospores are doubtlessly carried from plant to plant by the wind causing damp diseased leaves to flap against each other. After swimming about for a short time the zoospores burst and produce mycelium, which in turn reproduces the *Peronospora* after entering the host plant by the organs of transpiration. It is remarkable that at a time when little or nothing was known of zoospores in the *Peronosporeæ* that the Rev. M. J. Berkeley wrote in the *English Flora*, 1836, under *Botrytis crustosa*, Fr. (a synonym of *Peronospora nivea*, Ung.),—"the spores, very large and decidedly filled with sporidia, as in *Mucor*." See the description of *Mucor subtilissimus*, Berk., in this work. Oospores or resting-spores are produced within the tissues of the host plant; one of these, enlarged 400 diameters, is shown at D.

Often associated with *Peronospora nivea*, Ung., especially in the leaves and stems of *Ægopodium Podagraria*, L., a second fungus named *Protomyces macrosporus*, Ung., is found. The name *Protomyces* is derived from *protos*, first, and *mukēs*, a fungus; *macrosporus*, of course, means large-spored. The constant occurrence of the *Peronospora* with the *Protomyces* is very remarkable, but until better evidence is forthcoming we are inclined to look upon the phenomenon as a striking example of "consortism." We have

never seen the *Peronospora* in anatomical connection with the *Protomyces*.

An illustration of *Protomyces macrosporus*, Ung., is given in Fig. 113, enlarged 400 diameters. These bodies, which are true oospores or resting-spores, have two or three membranes, and when small in size, as at C, are hardly to be distinguished from the resting-spores of *Peronospora nivea*, Ung. When, however, they are of large size (and they vary greatly), and furnished with a dissepiment across the inner or endospore, as at B, they are unlike the usual resting-spores belonging to *Peronospora*. These bodies

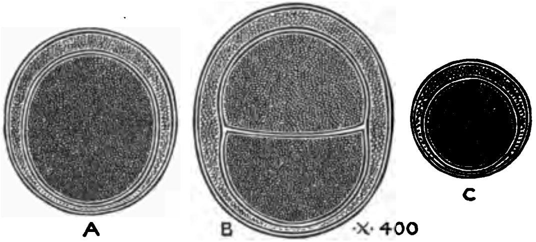


FIG. 113.
Protomyces macrosporus, Ung. Enlarged 400 diameters.

occur in the intercellular spaces within the leaves and stems of umbelliferous plants, often in large companies. They not only cause decomposed spots to appear, but they distort and distend the affected parts in a remarkable manner; so much is this the case that the presence of the fungus within is easily detected by the knotty swellings they set up. As the spores reach maturity they cause the tissues of the leaf to rot, and by this means they reach the ground by falling from the decayed places. They doubtlessly rest on and in the ground in a hybernating state till the following spring or summer. Mr. Berkeley says the *Protomyces* is probably one form of fructification of the *Peronospora*. In this he agrees with Caspary; but De Bary

states that the mycelium belonging to the two fungi is different, and that the oospores of *Protomyces* contain great numbers of very minute slightly oscillating spores, which escape from the expelled inner membrane as in Cystopus, conjugate in pairs like the conidia of the Smut fungus of corn, and produce *zygospores*, from *zygos*, a yoke, —in reference, we presume, to their supposed pairing. The zygospores on germination are said to be capable of penetrating, by their germinal filaments, the epidermis of the plant invaded exactly after the manner of *Peronospora*. The mycelium is said also to be only capable of effectually growing when within the special host plants of the *Protomyces*. In this position only are the oogonia and oospores, which at length bear the conjugating spores, produced. This habit is also the same with that of *Peronospora*. The so-called zygospores are minute transparent oscillating bodies without cilia ; they are about the same in size with (or perhaps a little smaller than) the zoospores produced by the conidia of *Peronospora nivea*, Ung., as illustrated at B, C, Fig. 112. True zoospores sometimes do not produce cilia, and it is by no means uncommon to see zoospores conjoined by a short band. The oospores burst and discharge the little conjugating zygospores in spring, again reminding one of the habit of *Peronospora*. Although we are inclined to esteem the oospores of *Protomyces* as different from the oospores of *Peronospora nivea*, Ung., yet there is evidently room for a different opinion. New observations are needed. Prof. de Bary's paper, *Beiträge zur Morphologie und Physiologie der Pilze*, was published in 1864.

Peronospora nivea, Ung., produces resting-spores within the stems and roots of the plants attacked (they occur in company with the oospores of the *Protomyces*) ; therefore all plants which have been attacked by these fungi should, as far as possible, be burned. As both the *Peronospora* and the *Protomyces* are peculiar to umbelliferous plants, parsnips should not be grown a second year in the place

where other umbelliferous plants have been invaded by mildew, as the resting-spores will be on and in the ground ready for attacking other umbelliferous plants on their germination in spring.

The mildew of parsnips has been seen on baldmoney, *Meum Athamanticum*, Jacq.; on burnet saxifrage, *Pimpinella Saxifraga*, L.; *P. Anisum;* parsley, *Petroselinum sativum*, Hoffm.; the garden and wild chervil, *Anthriscus Cerefolium*, Hoffm.; and *Chærophyllum sylvestre*, Linn.; and hemlock, *Conium maculatum*, Linn.

The common red-rust and black mildew of celery, another umbelliferous plant, is caused by *Puccinia apii*, Corda, and its *Uredo*, *U. apii*, Wall., a fungus closely allied to the rusts and black mildew of corn. This fungus has been proved to be hereditary, and its plasma capable of being transmitted in celery seeds. Celery is sometimes infested with *Puccinia heraclei*, Grev., a parasite frequent on cow-parsnip or hogweed. The Umbelliferæ are unusually subject to attacks from fungi.

CHAPTER XXX.

BUNT OF WHEAT.

Tilletia Caries, Tul.

The disease of wheat generally known as bunt is recognised in some districts as pepper-brand, smut balls, bladder-brand, stinking-smut, stinking-rust, and even smut. Its ravages are almost confined to cultivated wheat; it rarely occurs on barley. A distinct species occurs on wheat in the United States. The scientific name of the fungus which causes bunt in wheat is *Tilletia Caries*, Tul. *Tilletia* is named after Matthieu Tillet, who wrote the *Dissertation sur la cause qui corrompt et qui noiriet les grains de blèd dans les épis*, Bordeaux, 1755, and a similar work published in Paris in 1755. *Caries* means rottenness or decay. The meaning of the popular name, bunt, is very obscure. We have the word bunter, which means an offensive person (woman), and the verb bunt, to swell; the former may be a cognate derivative. Dr. Murray of Mill Hill informs us that the word bunt is used, for a fungus in the same way as touchwood, by writers of the seventeenth century. This is perhaps the most likely origin. The cavity or belly of a sail is called the bunt, and the material of the sail bunting. The bellying part of a seine-net is also called the bunt, which name may have been transferred to the blight in reference to its fishy smell. Bunt may be a corruption of burnt.

In the fields it is difficult without experience to distinguish bunted from sound wheat; there is very little indeed to indicate the presence of the hidden foe; this is why the disease is so dreaded by farmers. As in

many other fungoid ailments the fungus appears to excite an abnormal growth of chlorophyll, and the spikes of affected plants are commonly greener than the sound ones. Even on examining the ears it sometimes happens that but little seems amiss; it is not until the glumes and pales are pushed aside that the dark diseased seeds become visible. Sometimes the bunted grains burst whilst still in the ear, and the escaped spores stain the glumes and pales a dark colour. Practised eyes readily detect these slight black stains.

A bunted grain of wheat is illustrated at Fig. 114, A,

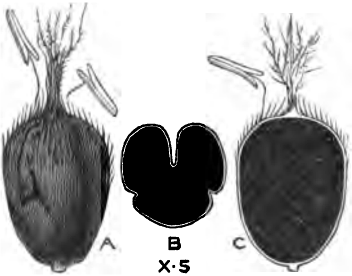


FIG. 114.—BUNT OF WHEAT.
Grains of wheat destroyed by *Tilletia Caries*, Tul.
Enlarged 5 diameters.

with a transverse section at B, and a longitudinal section at C, enlarged five diameters. Reference may be made to Fig. 42 for a normal grain of wheat, and to Fig. 45 for an example of ear-cockle, all engraved to the same scale. The external appearance of bunted grains of wheat is different from healthy grains. Bunted wheat seeds are shorter and wider than healthy ones; they are dwarfed in height and distended in width, and generally somewhat pointed towards the base. Instead of being pale buff in colour, they are of a somewhat dark, dull green tint. They are frequently cracked, as shown at A, and from

these cracks a black powder emerges. On cutting affected seeds in two, the outer coat of the grain is found to be weak and brittle, and its whole inner substance a mass of black powder, which has replaced the natural inner farinaceous material of the grain. On crushing bunted wheat between the fingers the black pulpy powder feels soft and greasy, and a fœtid odour resembling decaying fish is dispelled; hence the popular name,—stinking-rust. One of its old botanical names is *Uredo fœtida*, Baeur. Bunted grains do not occur as isolated examples in the ear; the rule is that every grain in an affected ear is bunted. When these bunted grains are ground into flour their

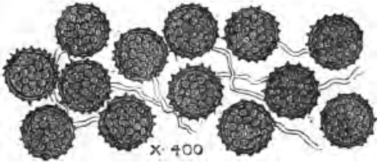


Fig. 115.
Spores of the Bunt fungus, *Tilletia Caries*, Tul.
Enlarged 400 diameters.

presence is made known to the miller, not only by the black streaks they cause in the white flour, but also by the disgusting odour which arises at the time of crushing.

The black powder, when placed under the microscope and magnified 400 diameters, is seen as at Fig. 115, one mass of beautiful brownish spores, with a few fine mycelial threads, to which some of the spores will be seen still attached; the supporting threads are best seen in young examples, for as the fungus approaches maturity, the threads break up into dust and perish. The spores are spherical, or sometimes slightly oval, reticulated and slightly spinulose, reminding a microscopist of pollen-grains belonging to the *Campanulaceæ*, the colour of course being different. They are so small that a single

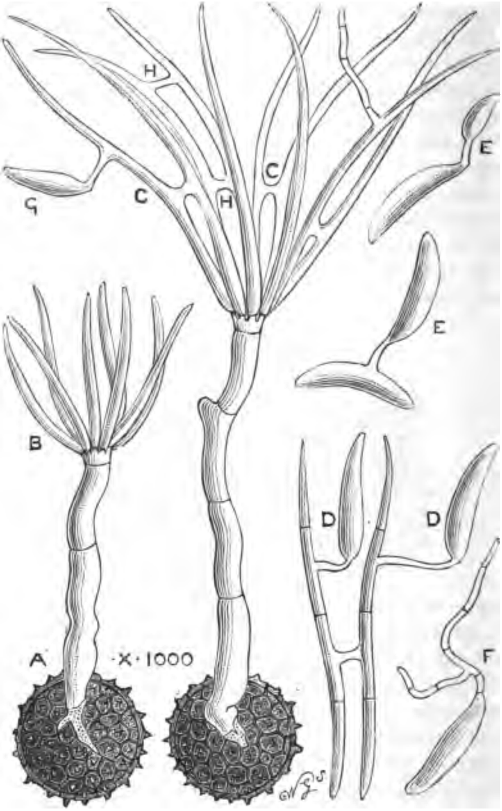


FIG. 116.—BUNT OF WHEAT.
Spores of *Tilletia Caries*, Tul., germinating.
Enlarged 1000 diameters.

grain of wheat is large enough to contain 4,000,000 of them.

If these spores are kept in moist air or on a wet surface for three or four days, they will germinate, as at Fig. 116, A, enlarged 1000 diameters. The epispore bursts, and a thick septate tube is protruded. This tube, after it has grown to three or four times the diameter of the spore, forms a sort of small terminal crown, and on the minute papillæ of this crown it bears four, eight, or ten rodlike sporidia, as shown at B. When these sporidia are fully grown, and whilst still adherent to the apex of the germ-tube, they coalesce, as at CC, by means of short transverse tubes. When these conjugated bodies drop from the supporting tube they germinate and produce secondary sporidia of a different form, as shown at DD. At times the supporting threads of these conidia are extremely long and jointed throughout; at other times there is no supporting thread, but the conidium may grow from the end of a secondary spore. Sometimes the sporidia are produced whilst the secondary spores are still attached to their supporting stem. A spore or conidium so growing is illustrated at G. The conidia, in turn, are capable of germination and the production of conidia of the third order, as at EE. Sometimes they so germinate without the spores, DD, falling from their attachment. When the secondary and tertiary sporidia, as at D and E, germinate, they produce a septate thread of extreme tenuity, as at F, and on this thread the bunt spores are at length borne, as illustrated in Fig. 115. Sometimes bunt spores do not produce, on germination, the minute crown-like terminal cell, with its conjugating secondary spores; but the thick germ-tube grows for a great length, branching and rebranching, and all the time forming septa. The vital material is chiefly confined to the terminal end of each branch. When this mode of growth takes place, conjugating spores are never formed.

In some instances the secondary spores become conjoined in two places instead of one, as illustrated by Mr. Berkeley, and confirmed in two instances by Dr. Oscar

Brefeld; in other cases three secondary spores may become conjoined, and it is not uncommon to see the conjugating band itself burst and produce a mycelial thread.

Under favourable conditions a few germinating secondary spores will form a dense involved mass of mycelium, bearing a vast number of conidia of the first and second generation; and under the microscope these may be seen in all stages of growth. When the mycelium for any reason ceases to grow, a crop of conidia is at once produced. Sometimes the mycelial threads become furnished with an enormous number of short joints or constrictions, giving the threads a necklace-like appearance. Ultimately this chain or necklace breaks up into separate joints, and each joint acts as a conidium. Each conidium thus formed in a chain is capable of producing other necklace-like growths of conidia.

An elaborate essay on bunt and smut was published in Paris in 1877 under the name of *Aperçu Systématique des Ustilaginées*, by Alexandre Fischer de Waldheim. This author at one time advocated the idea of bunt and smut fungi living in two forms on different plants in the supposed style of corn mildew on the barberry bush, because he failed to infect corn experimentally, and because he had probably learned that "experience had taught the practical farmer" that (according to Phillipar) the barberry bush, a stinking plant, when in bloom, was in some places the cause of bunt. No experiment is, however, easier than the artificial and direct infection of wheat with bunt and smut.

Wheat becomes affected with bunt by the spores of the fungus being sown with the grain. The spores do not germinate whilst they are dry and stored with the seed, but in and on the damp ground after the grain has been planted. The whole series of changes illustrated in Fig. 116 takes place on and in the ground, and when the attenuated thread at F is produced, it readily finds its way, aided by its inconceivable fineness, into the tissues

of the young wheat plant by entering the first-formed organs of transpiration in the infant plant. The spores themselves do not, of course, enter the stomata, and the germ-tubes probably do not attack the rootlets unless the latter are broken or injured, although it has been said by Le Maout and Decaisne, in their *General System of Botany*, that the spores can pierce the tissues of the roots. The germ-tube, when once within the infant plant, speedily ascends the stem. It is now by no means difficult to trace the course of the mycelium up the shaft of the affected plant, and an instance has been recorded by the Rev. M. J. Berkeley in vol. ii. of the *Journal of the Royal Horticultural Society*, 1847, where a streak of bunt appeared upon the outside of the stem of a wheat plant. Mr. Berkeley was the first to publish a description and illustration of germinating bunt spores, with the conjugating spores borne on the germ-thread. This was seven years before the publication of L. R. Tulasne's memoir in the *Annales des Sciences Naturelles, Botanique*, series iv., vol. i., 1854. Mr. Berkeley, although at first inclined to look upon these conjoined bodies as having something to do with the reproduction of bunt—the appearances seen in some *Algæ* indicating this to him—abandoned this first and correct opinion for the idea that the conjugated bodies were parasites of bunt. He described the growth as a *Fusisporium*, partly owing to the septate spores, under the name of *F. inosculans*. It is curious that Tulasne illustrated the conjoined spores of germinating bunt as non-septate, and therefore unlike a *Fusisporium*, and since 1854 this view appears to have been generally accepted as correct; but last year Dr. Oscar Brefeld, in his elaborate work, *Botanische Untersuchungen über Hefenpilze*, correctly illustrate the germinating secondary spores as furnished with septa, sometimes three and sometimes four, precisely in the style of *Fusisporium*. This observation, the correctness of which we are able to confirm, proves the accuracy of Mr. Berkeley's observa-

tion in 1847. The septa are best seen in the spores which have germinated and borne conidia, and such as have lost their vital material, as at DD, Fig. 116. For spores of *Fusisporium* illustrated to the same scale as germinating bunt, see Figs. 10, 11, 92, 94, and 96 in this work.

It is easy to prove that bunt in wheat is propagated by the spores of the fungus, for if wheat seeds are dusted with the spores or watered with water containing spores, every wheat plant will come up bunted; whereas neighbouring plants, if not so treated, will come up free from disease.

Bunt spores are said (perhaps on insufficient grounds) to be more or less injurious if mingled with flour and made into bread. We have frequently seen them in flour and bread, together with spores of *Urocystis* and other fungi. Bunt spores were, we believe, at one time supposed to be the cause of cholera, because they were found in cholera evacuations. Professor Hallier has erroneously referred cholera to the presence of *Urocystis occulta*, Pre., a fungus common in Britain on rye, as well as to bunt, as may be seen by his *Phytopathology*, and the reports of Drs. Cunningham and Lewis in the *Lancet* of 2d, 9th, and 16th January 1869. Fowls have been fed with bunted wheat without any bad result.

A fungus allied to bunt, but still nearer to smut, and named *Ustilago grandis*, Tul., is said to cause headache and other bad symptoms amongst the men engaged in cutting reeds for thatching, in consequence of their inhaling the abundant spores. The same fungus is said to cause eruptions on the face amongst the labourers of the South of Europe.

When bunt is known to be amongst seed grain it should be washed or steeped in some weak poisonous solution, as the minute spores from bunted grains adhere to the healthy seeds. Water, salt, quicklime slacked with boiling water; sulphate of copper, a quarter of a pound to a bushel of corn, and sulphate of soda have all been recommended.

Sulphate of soda in solution and the seeds afterwards dried with dusted quicklime is said to be one of the best preventive solutions. The lime combines with the soda and forms sulphate of lime or gypsum, whilst caustic alkali is set free. As the spores are lighter than water, mere steeping in brine or even pure water is often effectual, as the spores float, and are easily washed away. It is probable that the presence of a few scattered greasy spores are quite as, if not more, damaging than the whole bunted grains with unbroken seed coats. Some alkaline ley should be added if water is used, as the oil on the surface of the spores combines with the alkali and forms a soapy substance which is fatal to effectual spore germination. Sufficient permanganate of potassium may be added to the water until it becomes rose-coloured, or one per cent of carbolic acid may be mixed with the water. It is not proper for the seed to remain long in these solutions; they should be washed quickly and then allowed to dry. When millers see bunted grains amongst the wheat they generally pass it through a dresser with a strong exhaust, and this draws away the fœtid spores.

Bunt, *Tilletia Caries*, Tul., seems to be confined in this country to wheat, *Triticum vulgare*, Vill.; *T. sativum*, Lam.; and barley, *Hordeum distichum*, L. Alex. Fischer de Waldheim describes no less than fourteen species of bunt. Some of these, as *T. Lolii*, Awd., and *T. lævis*, Kuehn.; the first recorded on three different species of *Lolium*, and the second on five species of *Triticum*, including wheat, probably occur in this country. One species attacks five different species of *Agrostis*, and several other bunt fungi are confined to grasses.

A curious species of bunt named *Tilletia bullata*, Fl., has recently been found in Scotland on docks, *Rumex obtusifolius*, L. On the Continent this bunt attacks different species of *Polygonum*.

CHAPTER XXXI.

SMUT OF CORN.

Ustilago carbo, Tul.

THERE are few fungi more familiar to agriculturists than the common "smut" of corn, so common on wheat, barley, and especially oats. Its black colour, and its profusion of sooty spores produced on impoverished ears of corn, makes it apparent to the least observant. It appears earlier in the season than bunt, with which it is sometimes confounded by rustics. It is in some places called "bunt ear," "black ball," "dust brand," and "chimney sweeper." Its scientific name is *Ustilago carbo*, Tul. The generic name is derived from *Ustio*, a burning, and *carbo*, charcoal, in reference to the burnt and sooty appearance of the diseased panicle or spike. Farmers look on this fungus with less dread than the fungus of bunt, perhaps because the last is virtually a hidden foe and may cause unexpected sudden and serious loss, whilst smut is always seen, and indeed, makes itself obtrusively apparent. In some districts the loose smutted panicle of oats is ignorantly termed the male plant, the spores of the fungus being esteemed as black pollen, and so more beneficial than harmful. As there is no disgusting odour belonging to the "smut" fungus, it does not spoil the flour to an equal extent with the *Tilletia*. It is probably not very injurious if taken in food by animals, as fowls are not injured by eating smutted grain. It has, however, been said that the straw of corn that has been infested with the smut fungus is distasteful to cattle in chaff. In bad cases as much as one-third of

FIG. 117.
Panicle of oats invaded by the fungus of Smut, *Ustilago carbo*, Tul.
Natural size.

the crop has been destroyed by the presence of the smut fungus.

The general appearance of a panicle of oats affected with smut is illustrated, natural size, at Fig. 117. In the field it is evident that (as with bunt) the disease springs direct from the root, for it is common to see numerous stems, and every one diseased, springing from one base. It is equally clear that the disease traverses each stem from the bottom upwards, as the lower spikelets of the young

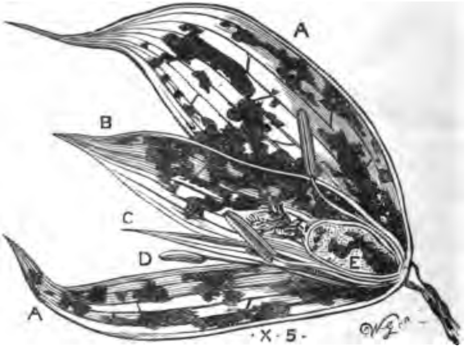
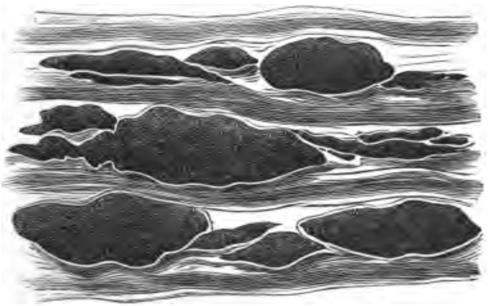


FIG. 118.
Part of a spikelet of oats with Smut fungus, *Ustilago carbo*, Tul. Enlarged 5 diameters.

panicle are the first to show the disease, as illustrated in Fig. 117. Nothing is more common than to see the basal branches of the panicle with their spikelets diseased and the upper part of the panicle presenting the normal healthy appearance.

Part of a spikelet only slightly affected with the smut fungus is illustrated in Fig. 118, enlarged five diameters. AA are the glumes; B, outer glumelle, sometimes furnished with a beard or awn; C, inner glumelle; D, abortive flower; E, the pistil or grain. The interior of the

diseased grain at first presents a whitish viscous mass, which is produced at the expense of the tissues and juices of the invaded plant. This viscid mass at length exhibits a structure of closely packed cells filled with a homogeneous mass of minute granules; the cell walls ultimately disappear, and the whole contents of the invaded organ appear as one black dusty mass of simple smooth spores. The disease is, however, by no means confined to the grain, as it attacks every part of the panicle with its spikelets, including their slender stems, with equal viru-



X ·25

FIG. 119.
Fragment of glume of oats, showing burst pustules of the Smut fungus, *Ustilago carbo*, Tul. Enlarged 25 diameters.

lence, till at last the glumes and other parts are left as transparent ragged fragments thickly coated with the masses of black spores, which have been produced at the expense of the normal tissues of the spikelet. If a fragment of an infected glume is now taken, and enlarged twenty-five diameters, it will be seen as at Fig. 119. This shows (horizontally) four of the fine ridges and three minute furrows, which can be almost seen with the unaided eye on every glume belonging to oats. The fungus bursts through the glumes and other structures

on both sides from within outwards, and as the spores increase in number they tear the epidermis of the invaded part to shreds, which shreds are, with the spores, speedily carried away by the wind. The pustules illustrated at Fig. 119 may be compared with the *sori* of a similar nature belonging to *Puccinia Rubigo-vera*, D.C., Fig. 67, and *Puccinia graminus*, Pers., Fig. 78. The spores are brownish-black in colour, roundish, and extremely small, as illustrated, enlarged 400 diameters, at Fig. 120. If the spores of bunt are now referred to, as illustrated to the same scale at Fig. 115, it will be seen how different they are in size. The spores of the smut fungus are so extremely small that it would take nearly 25,000,000 of them to cover a superficial square inch. They are also quite smooth, whilst the spores of the bunt fungus are reticulated and spinulose. Dr. Oscar Brefeld, in his work, *Botanische Untersuchungen über Hefenpilze Fortsetzung der Schimmelpilze*, Part V., states that some kinds of yeast are nothing more than conidial or larval forms of smut fungi. The reproduction of smut in the yeast condition continues for an indefinite period, so long as the spores are kept upon a suitable nutrient matrix. Upon this nutrient matrix they always remain in the yeast, conidial, or larval condition. If these views are correct they indicate that smut fungi are only truly parasitic during the perfect condition of their existence, and when in the yeast condition lead a non-parasitic life.

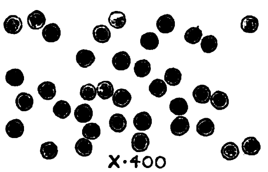


FIG. 120.—Spores of the Smut fungus, *Ustilago carbo*, Tul. Enlarged 400 diameters.

In Fig. 121 the spores of *Ustilago carbo*, Tul., are shown in different stages of germination enlarged 1000 diameters. The extreme smallness of these spores is very marked when compared with the large spores of *Peronospora Schleideniana*, Ung., Fig. 15, C ; *Puccinia graminis*, Pers.,

Fig. 80, and others engraved to the same scale in this work. Germination in water commences in less than twelve hours, as at 1 ; as germination advances buds or conidia are formed, as at 2, AA ; farther growth is seen at 3 and 4,

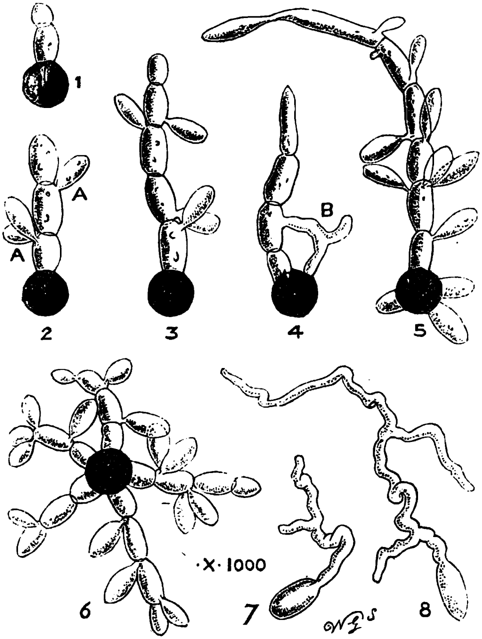


FIG. 121.
Spores of the Smut fungus, *Ustilago carbo*, Tul., germinating.
Enlarged 1000 diameters.

with fused or conjoined cells at B. This fusion is similar with the conjugation seen in *Tilletia*. Still more advanced growth is shown at 5 and 6. The long germ-tubes like the one illustrated at 5, commonly fuse with other germ-

tubes, and the two fused tubes will give rise to a third common conidium-bearing tube. Sometimes this tube is extremely long and fine, and furnished with numerous joints throughout its entire length. The conidia, as produced by the germ-tubes, are capable of producing other conidia by budding, till at last large colonies of conidia are produced in a yeast-like condition, free from the original *Ustilago* spore and its septate germ tube. The conidia, which are very unequal in size, germinate as at 7 and 8. Germination may take place at one or both ends or one or both sides, and the germ-tubes may fuse with each other at any point of contact. Sometimes the germ-tubes produced by the conidia are of almost inconceivable fineness and attenuation, but always more or less jointed throughout their entire length; the contained vital material is generally most abundant at the growing end. Sometimes, when growth has quite ceased, owing to unfavourable conditions, it is renewed with vigour under changed conditions, and new colonies of yeast-like conidia are formed, either from old threads or old conidia.

In the allied fungus named *Ustilago antherarum*, Fr., the conjugation of cells is very clearly seen, and lateral conidia are produced, as in *Tilletia*, Fig. 116, D, G. This parasite is common on the flowers of *Silene*, *Lychnis*, etc., in fields and hedge sides, reducing the anthers with their pollen to black dust. The conjugation is also very distinct in the spores of *Ustilago longissima*, Tul.; common on *Poa aquatica*, L., and *P. fluitans*, Scop. No doubt the so-called conjugation of cells is potential in all species of *Ustilago* and its allied genera.

We recently observed the germination of the spores of *Ustilago carbo*, Tul., under curious and natural conditions. We placed a large number of spores on the top of a flower-pot filled with moist white sand to note whether the spores would be readily filtered through the mass by rain. They did so filter in large numbers; but many of the spores germinated on the top stratum of sand, and

vast quantities of the transparent conidia were filtered through the sand on to the plate below; and in this position, beneath the bottom of the flower-pot and in the plate, they formed colonies of yeast-like conidia, and these conidia germinated by producing threads, as we have illustrated them in Fig. 121, 7 and 8. The spores germinate very readily and produce yeast colonies in diluted beer and diluted expressed juice of horse-dung.

The disease is doubtlessly propagated by the spores of the fungus being blown over the fields and absorbed by the earth, and by the fungus spores which adhere to the seed at the time of sowing. The black spores germinate in the ground, and there produce the secondary and tertiary series of transparent spores illustrated in Fig. 121. These spores or conidia of the second and third order at length protrude extremely fine germinal threads, and these threads find their way into the earliest produced stomata of the infant plant. The spawn or mycelium then travels up the stem towards the panicle and attacks the lowermost spikelets first. We have never noticed the upper part of a panicle diseased whilst the lower part has been sound. It may be commonly noticed that every stem, from two to eight or more, on an invaded plant, will show the disease, whilst adjoining plants remain free. The evidence therefore seems complete that the infection comes from the ground and travels upwards. It is obvious, therefore, that smut can only be prevented by dressing the seed, as in the case of bunt, and the directions for one apply to the other. A remedy against smut, much in favour in the north of England, and one which is said to never fail, is the preparation of the seed, immediately before sowing, with a sprinkling of stale urine, the seeds being afterwards raked in powdered quicklime till the seed is white. Sometimes the seed is prepared with vitriol or sulphate of copper solution, or "bluestone" dissolved in boiling water. One pound of "bluestone" dissolved in five quarts of water

is sufficient for a sack of four imperial bushels. The wheat is soaked for ten minutes, or the ten pints of solution may be poured over till all is absorbed.

Bunt, *Tilletia Caries*, Tul., is almost confined to two species of *Triticum;* but as smut invades many grasses found in pastures and waysides, the disease is clearly often nursed by the weeds. This fact points to the necessity for clean and careful farming. All smutted grasses, as well as the smutted panicles of oats, wheat, and barley, should be gathered in their earliest recognisable stages and burnt. A few common-sense hints given to the labouring men and boys would often save the employer from great losses.

The smut fungus *Ustilago carbo*, Tul., has been met with on the following grasses:—*Andropogon hirtus*, L.; *Cynodon Dactylon*, L.; hair grass, *Aira cæspitosa*, L.; oats, *Avena sativa*, L.; yellow oat grass, *A. flavescens*, L.; downy oat grass, *A. pubescens*, L.; *Arrhenatherum avenaceum*, Beauv.; species of *Melica;* fescue grass, *Festuca pratensis*, Huds.; *Brachypodium ciliatum*, P.B.; wheat, *Triticum vulgare*, Vill.; *T. turgidum*, L.; barley and barley grasses, *Hordeum distichum*, L.; *H. murinum*, L.; *H. vulgare*, L.; rye, *Secale cereale*, L.; rye grass, *Lolium perenne*, L.; darnel grass, *L. temulentum*, L.; rice, *Oryza sativa*, L.; and no doubt other plants. The different species of millet or sorghum, which in the south of Europe and some parts of Asia are grown for bread in the place of the oats and barley of northern Europe, are sometimes badly smutted. *Sorghum vulgare*, P., and *Setaria italica*, Beauv., are the chief food plants affected in India, Arabia, Asia Minor, Spain, and Italy.

Dr. Maxwell T. Masters, F.R.S., has recently detected a new British smut fungus, *Ustilago Kuhniana*, Wolff, on *Rumex Acetosa*, L.; and a second new species, *U. Candollei*, Tul., has been found on *Polygonum*.

CHAPTER XXXII.

TARE OR VETCH, AND PEA MOULD.

Peronospora viciæ, Berk.

LIKE several other species of *Peronospora* described in this work, *P. viciæ* was first detected by the Rev. M. J. Berkeley, and described and illustrated by him in vol. i. of the *Journal of the Royal Horticultural Society* in 1846.

This parasite is frequent on the under surface of the leaves of tares or vetches and field and garden peas. Although allied to *Peronospora trifoliorum*, D.By., as illustrated at Fig. 1, and *P. exigua*, W.Sm., Fig. 2, it is clearly distinct from both. Like the two plants just described, it grows within the foliage and causes brownish downy patches on the leaves and putrescence of the tissues. The conidiophores of the fungus grow in clusters, the spores are supported on long extremely slender spicules, and are tinted with a dull gray colour. *Peronospora viciæ*, Berk., is illustrated, enlarged 400 diameters, at Fig. 122; a single spore or conidium is farther enlarged to 1000 diameters at A. The spores on germination do not burst at the apex, but the germ-tube is generally protruded from the side. Damp close weather greatly favours the extension of this fungus, and dry weather retards its growth. It unfortunately happens that late peas are sometimes quite destroyed by another fungus named *Erysiphe Martii*, Lk., whose growth is favoured by dry weather and retarded by wet. When both fungi are present on one crop the destruction of peas is complete.

The resting-spores are brown, and at length reticulated

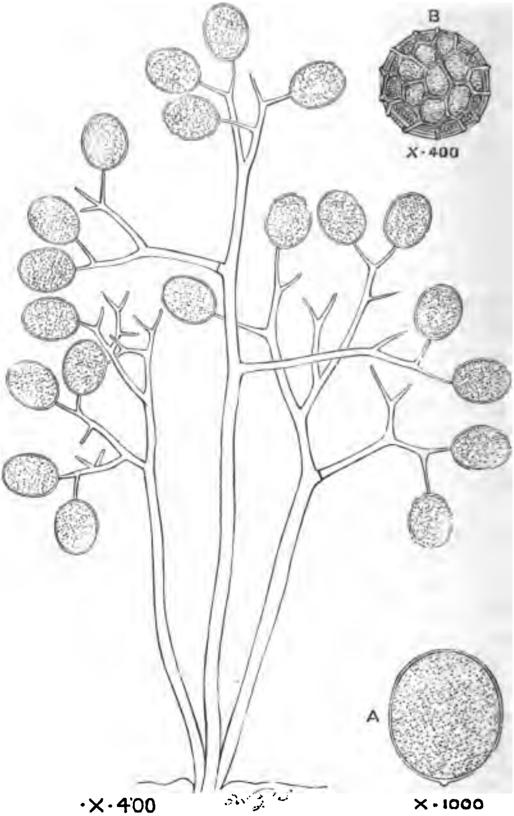


FIG. 122.—TARE OR VETCH, AND PEA MOULD.
Peronospora viciæ, Berk. Enlarged 400 diameters.
Conidium, A, 1000 diameters; Oospore, B, 400 diameters.

by the shrinking of the outer coat as illustrated, enlarged 400 diameters, at B. All diseased and decaying tare and

pea refuse should be gathered together and burnt, for it is in this material that the resting-spores hibernate during the winter, and burst into new growth in the early spring. Resting-spores are not destroyed by passing through the stomach of an animal as food. *P. viciæ*, Berk., is a distinctly early species as distinguished from *P. infestans*, Mont., the fungus of the potato disease, which is a distinctly late one. Being early, the late crops of peas are seldom affected by this parasite; they are, however, frequently destroyed by the fungus next described.

We have seen *P. viciæ*, Berk., growing within the pods of garden peas and upon the contained seeds.

This parasite has been detected on the bush-vetch, *Vicia sepium*, L.; the common vetch, *V. Sativa*, L.; slender vetch, *V. tetrasperma*, Mœnch.; *Lathyrus macrorrhizus*, Wimm.; and on many species of *Pisum* and *Orobus*.

CHAPTER XXXIII.

PEA MILDEW.

Erysiphe Martii, Lk.

The description given of *Erysiphe graminis*, D.C., the blight or mildew of grass, applies generally to *Erysiphe Martii*, Lk., of peas, beans, Umbelliferæ, etc. The species is named in honour of *Martius*, the famous botanist, and is the same with *E. Pisi*, Grev.

The general appearance of the fungus, as seen upon a

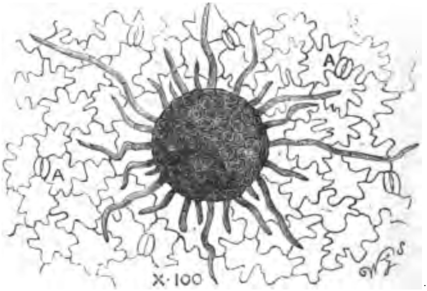


Fig. 123.—Pea Mildew.
Conceptacle of *Erysiphe Martii*, Lk., on leaf of pea.
Enlarged 100 diameters.

leaf of the pea under the microscope, is shown, enlarged 100 diameters, in Fig. 123. The dark body in the centre of the illustration is the conceptacle of the fungus, with its jointed tentacle-like appendages. The involved pattern in outline shows the epidermis of the leaf with its

numerous stomata as at AAA. The conceptacle or perithecium is distinctly smaller in size than in *E. graminis*. D.C., as illustrated in Fig. 57, and the cells forming the bark of the conceptacle are larger. Each conceptacle contains four or eight sporangia or spore cases, and each sporangium carries four to eight sporidia, as shown at Fig. 124, enlarged 500 diameters; this illustration may be compared with Fig. 60. The conceptacles arise from a dense woven mass of very fine white mycelium, omitted in Fig. 123 in favour of the epidermis of the leaf with its stomata. This mycelium is woven all over the stomata, and so one of the chief vital functions of the leaf, the transpiration of vapour, is arrested. The fungus grows on both sides of the leaves.

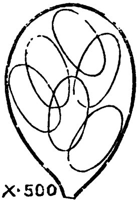


FIG. 124.
PEA MILDEW.
Sporangium or ascus, with spores, of *Erysiphe Martii*, Lk. Enlarged 500 diameters.

This destructive blight of peas invariably invades the late varieties, and is especially virulent in dry seasons. In small gardens the attack of the fungus may be prevented by keeping the peas well supplied with water. This treatment, however, cannot be adopted in the fields, and watering favours the growth of the *Peronospora* last described. Sometimes late peas are so badly attacked by this fungus that they appear as if thickly dusted with powdered chalk, and on the white surface thus formed the innumerable black conceptacles of the *Erysiphe* may be readily seen with the unaided eye. An attack of this fungus generally stops the growth of the invaded plants, and makes the production of pods impossible. The mycelium is provided with the minute suckers termed *haustoria*, and these *haustoria* pierce the epidermis of the attacked plant and cause decay. We have seen this fungus growing with its conceptacles inside the pods of peas.

It unfortunately happens that this parasite is not confined to peas; it sometimes grows on beans and melilot, plants belonging to the same family with the pea. It is, however, able to support itself on plants of St. John's wort, *Hypericum;* some umbelliferous plants, and the meadow-sweet, *Spiræa Ulmaria*, L. It is thus capable of growing effectually upon plants belonging to four different natural orders.

The only known preventive against attacks of this pest is the destruction by fire of all invaded material. The fungus is preserved in decaying refuse; in this material the little brown conceptacles remain intact during the winter, and in the following summer they burst, and each example discharges about fifty little living transparent spores, as shown in Fig. 124, ready to grow on the leaves of peas, weave a spider-weblike mycelium over the surface, and pierce the epidermis.

CHAPTER XXXIV.

LETTUCE MILDEW.

Peronospora ganglioniformis, Berk.

THE putrefactive fungus of lettuces was detected by the Rev. M. J. Berkeley, and described and illustrated by him in vol. i. of the *Royal Horticultural Society*, 1846. The specific named *ganglioniformis* refers to the resemblance of the fruiting-threads of the fungus to the natural enlargements termed ganglions in the course of a nerve. Tulasne thought this parasite was a mere variety of *P. parasitica*, Pers., as found on cabbages and illustrated in this work at Fig. 29; but a reference to our illustration of *P. ganglioniformis*, Berk., enlarged at Fig. 125 to 400 diameters, as compared with *P. parasitica*, Pers., enlarged in Fig. 29 to 200 diameters, will show how distinct the two are from each other. Professor de Bary disapproved of Mr. Berkeley's specific name *ganglioniformis*, and substituted *gangliformis* for it, considering the latter more correct, but no alteration was required. Had it been necessary, the word *gangliiformis*, as printed by Dr. Max Cornu, would be most correct. In both *P. ganglioniformis*, Berk., and *P. parasitica*, Pers., the fruiting-stems or conidiophores and branches are flattened, and as these flattened stems and branches twist a little in the process of growth, they have a spurious appearance of swelling in a ganglionic manner. Each ultimate branchlet of *P. ganglioniformis*, Berk., is beautifully dilated into a saucer-like expansion, with a single excessively-attenuated spicule growing from the centre of the saucer, and with from three to five similar minute spicules growing round

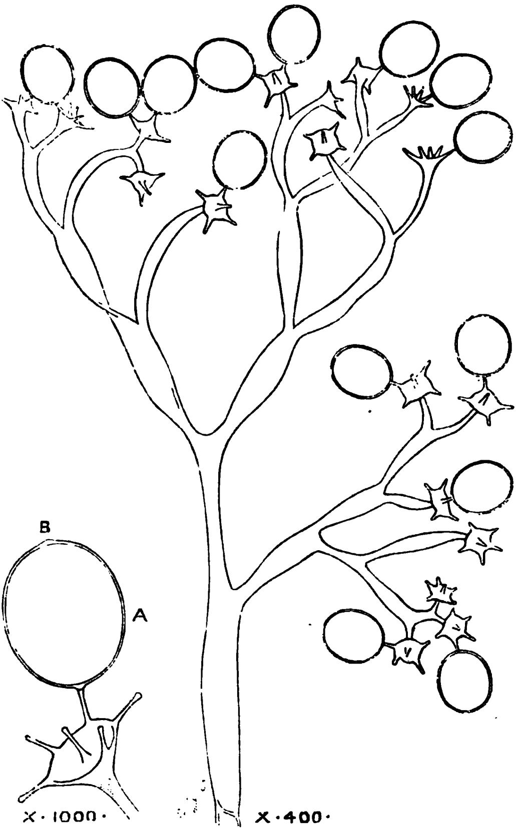


FIG. 125.—LETTUCE MILDEW.
Peronospora ganglioniformis, Berk. Enlarged 400 diameters.
Tip of branchlet with spicules and conidium, 1000 diameters.

the saucer's edge. Each spicule is like one of the

glandular hairs of a sundew leaf, or like a snail's tentacle with its eye-bulb. *P. parasitica*, Pers., has no saucer-like expansions. One of the exquisitely fine tentacle-fringed saucers with a spore, balanced on one tentacle, is enlarged to 1000 diameters at A. At the top of the spore at B, a small, almost invisible, *papilla* may be seen. This is the weakest point of the spore, and at the time of germination this part dissolves away or bursts, and the contained material pours out as a germinal thread. The spawn threads of this species grow within and upon the leaf, and attach themselves to the constituent cells in a manner similar with the cabbage *Peronospoar*, illustrated at Fig. 29. In whatever part of the leaf or stem the spawn grows it there sets up putrescence. The mycelium within the leaf is thick and coarse, and much too stout for emergence through the organs of transpiration. To meet this difficulty the spawn becomes naturally flattened as it approaches the stomata, and it emerges through the little slit on the under surface of the leaf, with a chisel edge, as does *P. parasitica*, Pers., see Fig. 30. As soon as the spawn thread of *P. ganglioniformis*, Berk., reaches the air it commonly branches, and, instead of a single fruiting-branch depending from each stoma there may usually be seen a small bunch of threads or conidiophores.

This parasite causes pallid patches of decomposition to appear on lettuce leaves, and on the margin of these patches little white knots of the destructive mould may be readily seen with the unaided eye. In the spring the pest generally shows itself first on the outside leaves near the ground where the air is still and humid, and grows inwards to the heart of the lettuce, carrying decay in its course. In bad cases summer lettuces are quickly reduced to putrescent masses. In the autumn the flowers and seeds are chiefly damaged; sometimes the harvest of seeds is totally destroyed. Thickly sown plants are worst affected. The fungus lives on the lettuces all the season, from spring to October.

It frequently happens that young lettuces grown in frames in the spring are badly attacked, and in many instances wholly destroyed; the equable warmth and humidity of a plant-frame is highly favourable to the growth of this fungus. When frame lettuces are attacked, a good plan for the destruction of the fungus is to give as much air as practicable, and if possible to leave the frames open for at least a part of one cold night. A short exposure to cold or slightly frosty air will not materially hurt the young lettuces, but will so cripple the vitality of the fungus that the lettuces, on being planted out, will often be found quite free from the parasite. With both lettuces and onions, however, it has been observed that transplanted examples are often the weakest, and these weakest plants are worst affected by their respective mildews.

The existence of *Peronospora ganglioniformis*, Berk., is preserved through the winter by the means of oospores or resting-spores. The resting-spores may sometimes be easily found in the old rotting stems of lettuce plants which have been destroyed by the fungus. They are generally most abundant between the spiral vessels and the external shells of old lettuce stems. A group of the resting-spores, as found by the Rev. J. E. Vize, near Welshpool, is illustrated at Fig. 126, enlarged 400 diameters. The oospores grow in enormous conglomerated lustrous masses: so profuse is this, their natural habit of growth, that under the microscope the masses of oospores look like the shining roe of some fish. As in the fungus of the potato disease, the resting-spores not uncommonly grow within the spiral vessels as illustrated. These oospores hibernate in rotting lettuce refuse during the winter, and germinate in the early spring. On germination the first produced conidia perish, unless they alight on lettuces or other suitable plants. When garden lettuces are not near, the fungus is nursed by several common cruciferous weeds; of these the worst is said to be the common groundsel, *Senecio vulgaris*, L. The statement is

a common one in text books that *P. ganglioniformis*, Berk., does not produce oospores in lettuces, or *P. infestans*, Mont., oospores in the potato. Our experience has been the reverse of this.

Peronospora ganglioniformis, Berk., grows on various other living composite plants in addition to the garden lettuce, *Lactuca sativa*, L., and *L. altissima*, M.B. Of these the different sorts of sow-thistles, as the corn sow-thistle, *Sonchus arvensis*, L., are most often attacked; then

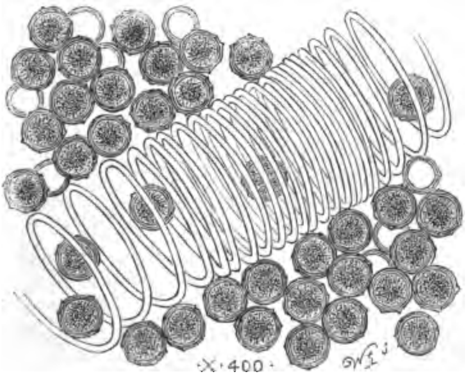


FIG. 126.
Oospores or resting-spores of the fungus of Lettuce Mildew, *Peronospora ganglioniformis*, Berk. Enlarged 400 diameters.

Carduus arvensis, Curt.; *Cichorium Endivia*, L.; the nipplewort, *Lapsana communis*, L.; groundsel, *Senecio vulgaris*, L.; and other plants, both wild and cultivated. Weeds act as nurses of the fungus for the garden lettuce.

For the prevention of the disease it is desirable that no decaying lettuces or weeds belonging to the series just mentioned be allowed to rot in the fields or kitchen

gardens where lettuces are grown; such material, where possible, should be carefully gathered together and burnt. Old lettuce stumps left in the ground are especially dangerous, as in these decaying stumps the resting-spores of the mildew often exist in myriads.

CHAPTER XXXV.

POTATO DISEASE, I.

Peronospora infestans, Mont.

ITS ACTIVE STATE.

THE question is often asked, When did the potato disease first appear? No one is able to answer this question. The fungus which causes the disease is, like the potato itself, of exotic origin. *Peronospora infestans*, Mont., grows on the wild potato plants of Peru. The strong probabilities are, that ever since the potato plant has existed, there has also been the putrescent fungus to prey upon it. The family of parasites to which the potato fungus belongs existed in geological times, long prior to the potato plant or any of its relatives.

It is important to remember, in the consideration of this subject, that the potato and its immediate allies are not the only plants destroyed by the potato fungus, for various members of the family to which the potato belongs also fall before the parasite. Of late years, in some districts the out-of-door cultivation of the tomato, *Lycopersicum esculentum*, Mill., has been quite stopped by the ravages made upon it by the potato fungus. All the species of *Lycopersicum*, of which we have at least eight forms in our gardens, are commonly attacked by the fungus of the potato disease. Sometimes the pest may be seen growing upon the henbane, *Hyoscyamus niger*, L., or common bitter-sweet, *Solanum Dulacamera*, L., of our hedges; at other times it may be observed upon various other species of *Solanum*, as *S. demissum*, Lind., and *S. cardiophyllum*,

Lind., or on the *Petunias* of our gardens. Sometimes the parasite may be seen upon an entirely different natural order of plants from that of the potato; it may leave the *Solanaceæ* and prey upon members of the *Scrophulariaceæ*, as the New Holland plant named *Anthocercis viscosa*, R.Br., or, as pointed out by Professor de Bary, the Chilian *Schizanthus Grahami*, Gill. We have both these plants in our gardens. It is worthy of note that there is a second species of *Peronospora* met with on Solanaceous plants, named *Peronospora Hyoscyami*, P., and peculiar, or nearly so, to the common henbane, *Hyoscyamus niger*, L. *Hyoscyamus* is by no means common in Britain, but its parasite has been recorded from a single locality near Market Deeping.

Circumstances might have been, and probably were, adverse in this country to a rapid spread of the potato fungus soon after the first introduction of the potato. At length the time arrived when circumstances changed, and something—it is impossible to say what—greatly accelerated the growth and vigour of the fungus. When the potato and its parasite were transferred from South America to Northern Europe, the climatic conditions were changed, and the potatoes were grown in a new, artificial, and unnatural manner. The constitution and habit of the potato also became changed,—we do not say weakened, although this may be the case, but altered. At the time of the alteration or modification of the nature of the potato plant, the potato fungus acquired greater potency over it. The same phenomenon has occurred with the tomato: as the plant has been gradually altered in habit by cultivation, so the habit of the assailing fungus has varied. There is no evidence to show that the *Peronospora* has altered in the least in the potency or non-potency of its attacks upon our neglected wild plants.

The first accounts of the potato disease in Europe are very obscure, but as our business is less to detail the history of the fungus than to describe it with its effects,

we shall dismiss this part of the subject briefly. Mr. Berkeley, writing in vol. i. p. 9 of the *Journal of the Royal Horticultural Society*, stated that at that time, 1846, a "very serious disease" had existed for more than half a century under the name of "Curl," which committed "immense ravages" in the north. At the present time we know that the "Curl" was, and still is caused by the fungus of the potato disease, *Peronospora infestans*, Mont.

In a communication to the French Academy, 17th November, 1845, M. Boussingault wrote, on the information of M. Joachim Acosta, that the malady was well known in rainy years at Bogota, where the Indians live almost entirely on potatoes. There was a disease of potatoes in 1815, and a second noticed under the name of "Dry Rot" in Germany in 1830; if this "Dry Rot" of potatoes was equally moist with the "Dry Rot" of timber, it would exactly agree with what we know of the potato disease now. It must be remembered here that *Fusisporium Solani*, Mart., often really dries up and destroys potato tubers. The year 1830 was not a year of daily newspapers, of sharp scientific observers, and students of the microscope. It may therefore be reasonably concluded that if potatoes were sufficiently diseased with "Rot" in 1830 to warrant a published account of the disease, they most probably were diseased to a less extent for several previous years, and probably before the year 1815 just mentioned. Many articles appeared in the newspapers and agricultural periodicals of 1833 regarding the "Rot" of potatoes in the northern counties of England (see *Journal of the Royal Horticultural Society*, vol. iii. p. 22). In 1840 the disease was widely spread in Germany and France, and in 1841 it again attracted great attention in Belgium. A sharp observer, Dr. Morren, at that time advised that the putrid stems should be immediately removed from diseased potato plants—a piece of advice which, under proper conditions of the growth of the potato tuber, might be followed with good results at the present day.

In the same year it was recorded in Vik, in Norway, by Mr. Westrem, the director of the Agricultural School. During the next year it had greatly extended itself and was recorded from Sogndal, as well as from Denmark in both years. In 1843 the disease was very destructive in Western Jutland, and in 1844 the potato disease was epidemical in St. Helena and Canada. From the published accounts of the periods mentioned, it may be seen that the potato murrain was then exactly as we see it now. It appeared at a similar period of the year, and during the typical moist warm weather so favourable to the growth of the fungus. The dark disease blotches were on the leaves and the tubers were murrain-stained and rotten. The offensive odour so familiar to us now was then specially noticed. The next year, 1845, was the ever memorable year of the great outburst of the potato disease over Western Europe, from Norway to Bordeaux, and the northern parts of the United States. In 1845 the fungus of the potato murrain acquired its greatest possible power for destruction. It was first noticed in the south of England in the middle of August, and in a fortnight it had spread over every part of the British Isles. So apparently sudden and destructive was this attack, that in the month of September it was hardly possible to procure potatoes unstricken by the murrain. From 1845 till now we have never been free from the assailing fungus; sometimes the attacks are extremely virulent—at other times slight; sometimes the fungus is common on various field and garden plants allied to the potato—at other times very little of the fungus is to be seen. Mr. Duncan Stuart has stated in the *North British Agriculturist* for 3d October 1883, that the fungus of the potato disease has never yet appeared in the Island of Rum, fifteen miles from the mainland, on the west coast of Scotland, and seven miles to the south of Skye. An exhaustive account, and the best ever written of the rise and spread of the potato disease in Europe, is given in the first volume

of the *Journal of the Royal Horticultural Society*, from the pen of the Rev. M. J. Berkeley. This paper also gives a complete description of the potato fungus,—a description so complete and admirable that, even now, very few new facts can be added to it. Since 1846, when that account was published, many fresh observers have written on the potato fungus, and some of Mr. Berkeley's original observations have been amplified, enlarged, and curiously confirmed.

The potato disease is seldom seen in Europe before July or August, although its appearance has been noted on rare occasions in May and June. Mr. Jensen has stated that the fungus of the potato disease cannot exist in any country where the mean temperature exceeds 77° Fahr. for any length of time during the period when the fungus generally perfects itself, and that in a temperature of 34° it cannot produce either mycelium or spores. It is generally first distinctly seen in the midland and southern counties of England between the 20th and 31st of July. It generally appears during close humid weather, when there are mists in the fields in morning and evening, and the days are hot, damp, and possibly stormy. Many other fungi suddenly perfect themselves under exactly similar meteoric conditions. It will be pointed out later on why it is, as we think, that the potato fungus appears with apparent suddenness under these conditions and at this particular time of the year. In the meantime it may be noted that the fungus generally makes itself manifest to the less experienced observer as a fine white bloom on the leaves, accompanied by dark putrid spots. The bloom is sometimes more profuse on the lowermost leaves of potato plants, not because the fungus has travelled up the stem from the seed tuber, but because the air is more moist and stagnant near the ground. The bloom, with its accompanying black disease blotches, soon travels to the stems, and when at length the tubers are reached the exhausted seed tuber (the weakest part of the plant) is commonly

traversed in every part by the spawn of the fungus. During warm, humid conditions of the weather the black decomposed spots are sometimes present for several days on the leaves before the fungus is seen. These blotches indicate that the putrefactive spawn of the fungus is within the leaves, awaiting favourable conditions for its complete development as a white bloom outside. The phenomena just mentioned are accompanied by a peculiar and very offensive odour well known to every person who has walked through a field of potatoes suffering from disease. The odour is caused by the putrescence set up in the tissues of the host plant by the contact of the mycelium of the potato fungus. Although the attack of disease in potato plants is apparently sudden, and made on apparently sound plants, yet all known facts point to the probability of the existence of the fungus in a nascent state during at least several weeks prior to its general recognition. The belief in the extreme suddenness of fungoid growths is, in many instances, a mere popular delusion. The common field mushroom is supposed by rustics to grow in a single night; but it is well known to careful observers that the infant mushroom exists just beneath the surface of the soil in a growing state for several weeks before it suddenly bursts through the earth and expands its cap or *pileus*. We have ourselves seen fields of potatoes which were apparently undiseased one day, prostrate on the ground the next, and the haulms blown away by the wind on the third day. This apparent suddenness of the attack in the early autumn appears to be well known in America; for Professor W. G. Farlow of Harvard University writes in reference to the "Potato Rot." (*Bulletin of the Bussey Institution*, part iv. p. 319): "At times its advent is so sudden that, within a few hours, the potato fields change from green to brown and black, and the plants which, in the morning, gave promise of an abundant crop, before night present a mass of decaying vegetation, in which are involved not only the

leaves and stems, but also the tubers." The following interesting and instructive sentence occurs in an excellent essay written by Dr. W. Peard, LL.B., on "Certain Enemies of our Roots," and published in the *Journal of the Bath and West of England Society and Southern Counties Association*, vol. iv., third series, p. 14 :—"At that time (Aug. 1845) we were spending some weeks at Ballyshannon, and close to our cottage was a magnificent field of potatoes, about twenty acres in extent, through which we passed regularly every morning and evening. One day, during the last week in August, as we brushed through the dark-green foliage, earthy disagreeable odours, before unknown to us, rose from the plants. On the following morning the entire crop looked as if it had been exposed during the night to the action of steam. Stems and leaves were soft, pulpy, and blackened ; in six-and-thirty hours a few sickly stems and discoloured leaves were all that remained. The crop had ceased to exist."

Mr. J. G. Baker, F.R.S., of Kew, is of opinion that the potato plant, *Solanum tuberosum*, L., in its present "tuber-bearing state is in a disorganised, unhealthy condition, a fitting subject for the attacks of fungi and aphides ;" and he quotes Mr. T. A. Knight to the effect that the formation of the tubers more or less deprives the potato plant of its requisite amount of nutriment. He considers that the potato is grown in a necessarily unnatural way in masses in our fields, instead of in isolated examples as in Nature ; and that the fact of the almost total absence of flowers and fruit in many cultivated varieties shows that the plant is in a disorganised state. Mr. Baker, from an examination of a large number of examples, has come to the conclusion that all the garden varieties have originated from *S. tuberosum*, L. Out of 700 or 900 species of *Solanum* it appears that only six produce tubers or potatoes at all ; the rest "maintain their hold on the world as most plants do, by their flowers, fruits, and seeds."

Other observers hold an opinion at variance with the

one advanced by Mr. Baker, and say it is impossible to over-cultivate any plant; that seedling potatoes are as badly affected as those grown from cut tubers; and that animals and plants placed in an artificial position by man only need an extra amount of care corresponding with their new position. Race horses are said to live as long as cart horses, domestic as long as wild animals, and the delicate children of towns as long as the more roughly nurtured children of country villages. It is acknowledged that extra care is required, but it is maintained that the constitution is not impaired.

In the potato disease, as in every other disease, both of animals and plants, it is necessary that the ailment should be completely understood before any serious attempt can be made towards the prevention or palliation of the attacks. We will, therefore, closely examine the structure and mode of growth of the potato fungus.

For an exact examination of *Peronospora infestans*, Mont., a very minute and extremely thin and transparent slice must be cut from a diseased leaf at a spot where the white bloom caused by the presence of the fungus is visible underneath. A good plan is to cut a diseased leaf in two through a disease spot, and then with a sharp lancet cut an extremely thin slice off from one of the exposed cut surfaces. If the slice last cut is somewhat longitudinally wedge-shaped, it will often best show the structure of the leaf and the contained fungus at the thinner end of the section. Such slicing requires great care and experience, and the art is only acquired after many failures. To those, therefore, who are unequal to the task we advise the purchase of slides ready prepared by the Rev. J. E. Vize. The atom to be examined should be placed on a glass slide in a drop of glycerine (this is preferable to water, as the latter often dries too quickly), and then covered with a clean thin cover-glass.

The magnification given by an ordinary lens is useless for the observation of the minute fungus now before us, so we

must at once place it under the higher powers of the microscope. If the slicing through a disease spot is successful, we shall probably see the atom when magnified 100 diameters, as at Fig. 127. The thickness of the lamina of the leaf is shown at A, B ; the under side of the leaf is represented at A, from which surface the fungus almost invariably springs. The fungus, therefore, really grows downwards. The true upper surface is shown at B. This reversal of the leaf in the illustration is merely, as in other instances in this book, to show more clearly the treelike branching growth of the fungus. If we confine our attention for the present to the section of the leaf, we shall note that it is made up of minute bladder-like cells, loosely packed together; and that the cells at top and bottom, representing the lower and upper cuticle of the leaf, are devoid of the shading, which is meant to indicate the green colouring matter or chlorophyll within. An opening into the interior of the leaf will be seen at C ; this is one of the stomata or organs of transpiration, sometimes referred to as "breathing pores." The stomata are like the gates to a camp or to an entrenched position ; they are the weak points through which an enemy may enter, and when once these gates are passed, the whole interior of the plant is at the mercy of the invader. At D may be seen a hair built up of four transparent cells, the two lower being traversed by a mycelial thread of the potato fungus. On the upper part of this hair, attached to the outside at E, may be seen one of the small branches of the fungus ; this branch has burst and thrown out a mycelial thread from its side. Every fragment of the potato fungus is capable of growth, and of ultimately reproducing the parent fungus. The cells immediately under the true upper cuticle of the leaf at F are termed pallisade cells ; and their disposition in the manner illustrated serves to give the necessary firmness to the exposed upper surface of the leaf.

If we now look within the fragment of the leaf we

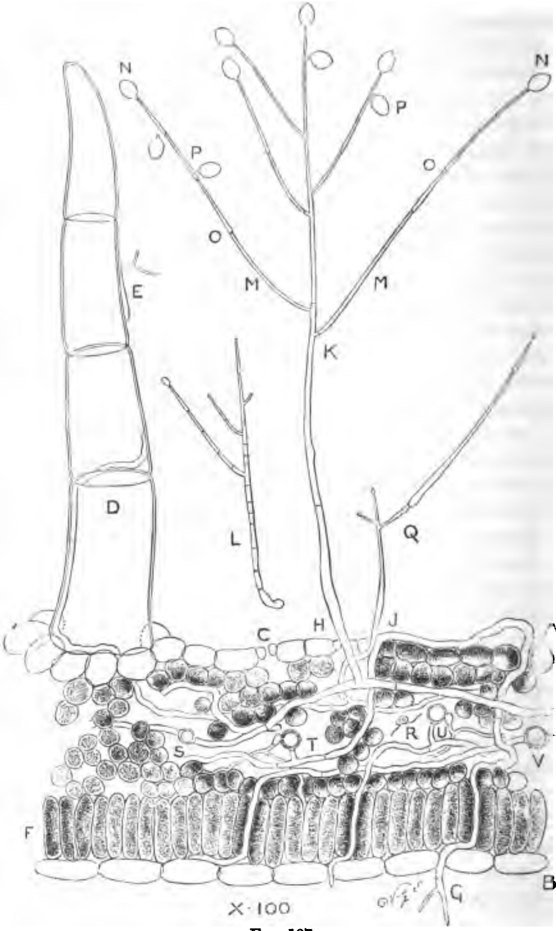


FIG. 127.
Section through a fragment of a potato leaf, with the potato fungus, *Peronospora infestans*, Mont., growing within its substance, and emerging through the epidermis. Enlarged 100 diameters.

see transparent threads running between the small spherical leaf-cells; these are the spawn-threads or mycelium of the fungus. It should be especially noticed that wherever the spawn touches the cells it discolours them (as indicated by the darker shading), and causes putrescence by contact. If we again look at the pallisade cells near G, we observe that a spawn-thread has pushed itself between them and between the cells of the upper cuticle, and is emerging into the air. If we trace the spawn-threads to the organ of transpiration at H, we notice that a thread in its passage from the body of the leaf has blocked up a so-called mouth. This choking prevents the transpiration of vapour, and hastens putrescence. Two other threads have pushed themselves between the leaf-cells at G and A. When the larger of the emerged threads is traced upwards to K, a treelike growth is noticed; and this branching form is the fruiting condition of the fungus of the potato disease called *Peronospora infestans*, Mont. The name *Peronospora* has been explained; *infestans* needs no explanation. The whole fungus is perfectly transparent, like colourless glass, and extremely fine, thin, and attenuated in all its parts. Some book illustrations give a very erroneous idea of the fungus, owing to the use of thick lines and an unnatural amount of dark shading. We notice as a rule that the fruiting-stems or conidiophores, as at K, have comparatively few joints or septa; sometimes, however, old examples, as at L, are full of joints. If we now look at the branches MM, we observe that each is surmounted by a transparent spore, technically termed (as in other species of *Peronospora*) a conidium as at NN; and to these bodies we shall more specially refer further on. It must also be noticed that all the branches are more or less constricted or jointed in a peculiar manner, as at OO; and that each joint has at one time carried a conidium, the lower conidia having been pushed off as the branches have continued their growth, as at PP. Sometimes a weakly im-

poverished thread, if grown in dry air, will quickly become strong and robust in growth if transferred to warm moist air, as in the thread illustrated at Q. In many species of *Peronospora* the branches which carry the conidia only produce one conidium, and do not continue growing and producing new conidia. Owing to the mode of spore production in the potato fungus, Professor De Bary has recently suggested that the parasite should be placed in a new genus by itself under the name of *Phytophthora*. Other botanists, however, as the Rev. M. J. Berkeley and ourselves, would prefer reducing rather than increasing the genera of the *Peronosporeæ;* and so include in *Peronospora* not only *Phytophthora* but *Ovularia* and even *Ramularia*.

At Fig. 128 we have engraved a fragment of the potato fungus to 400 diameters, so that the parts may be compared with the other species of *Peronospora* engraved to the same scale in this work. A considerable difference will be observed if Fig. 2 and Fig. 16 are referred to. The spores or conidia are shown at A, Fig. 128, and the peculiar constrictions in the jointed branches are better seen. If ripe conidia are placed in water it will be noted that a differentiation of the contained protoplasm takes place, as shown at BB; and that the interior mass of each conidium becomes divided into from five to nine or more portions, each contained portion being furnished with one or two lustrous vacuoles. These differentiated portions speedily emerge from the top of the conidium when placed on any moist surface as at C; and each portion now free, becomes quickly furnished with two extremely fine hairlike cilia, tails, or vibrating hairs, as at D. These secondary spores or zoospores are able to sail about in the slightest film of moisture. After a brief time the little motile zoospores or animal-like spores rest and take a globular form, as at E, and the vibrating hairs dissolve away or drop into the finest dust. After a short rest the now quiescent

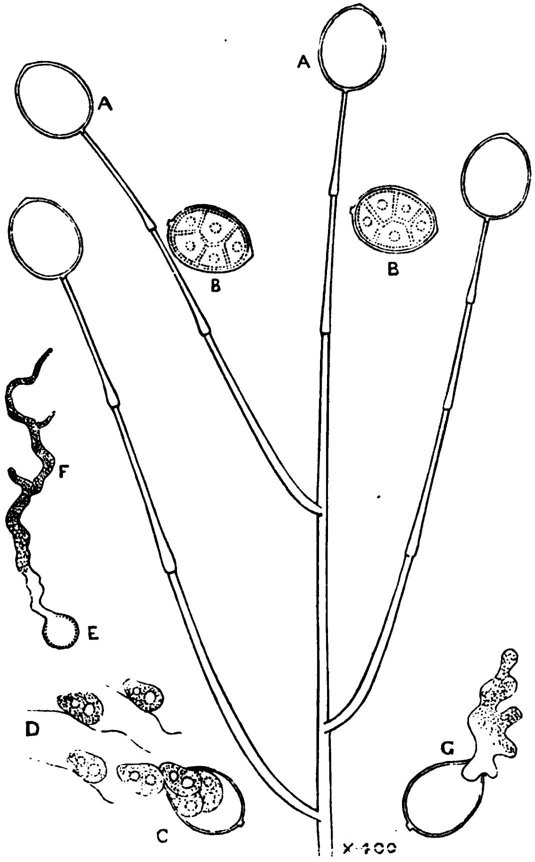


FIG. 128.
Fragment of the upper part of a conidiophore of the potato fungus, *Peronospora infestans*, Mont., with conidia and zoospores germinating. Enlarged 400 diameters.

zoospores burst and produce a thread of spawn, as shown at F; this germinal thread is capable of carrying on the existence of the potato fungus. Zoospores were first discovered in the genus *Cystopus*, allied by some authors with *Peronospora* (see chapter xvi.), by Prevost in 1807; and Mr. Berkeley described and illustrated them in the potato fungus, though he did not see the vibrating hairs, in 1846, *Journal of the Royal Horticultural Society*, vol. i. pl. 4, fig. 18. Sometimes the conidium, which, when it bears zoospores, is really a sort of spore-case, sporangium, or zoosporangium, does not differentiate within, but bursts

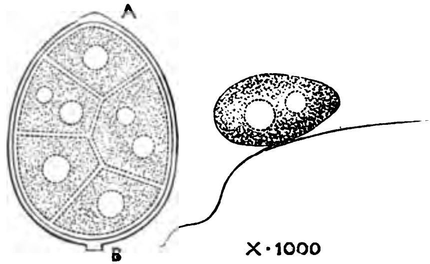


FIG. 129.
Conidium or zoosporangium and zoospore of the potato fungus, *Peronospora infestans*, Mont. Enlarged 1000 diameters.

and protrudes a small mass of protoplasm or vital material, as at G, Fig. 128. This mass speedily elongates into a mycelial thread capable (like the thread from the zoospore) of carrying on the life of the potato fungus. A ripe conidium or zoosporangium and zoospore of the potato fungus are farther enlarged to 1000 diameters at Fig. 129, for comparison with other reproductive bodies illustrated to the same scale in this work. A considerable difference in the size of zoospores will be noted if Figs. 33 and 39 are referred to. The soft papilla or bursting point of the zoosporangium is shown at A, Fig. 129; and the minute footstalk by which the zoosporangium was

originally attached to the stem of the parent fungus at B. It must be specially noted that water or moist air is essential for the existence of the fungus, for nearly every part speedily perishes in dry air, heat, or frost. When the conidia burst and set free the minute zoospores, the latter sail over the damp surfaces of leaves, and even float into the organs of transpiration. A zoospore swimming in an intercellular space is shown at R, Fig. 127. One has only to imagine a large field of potatoes, with all the leaves moist and swaying backwards and forwards with the wind, to perceive that such a field, say on a warm misty morning or evening, would form a sort of continuous lake of moisture on which the zoospores could float from one plant to another. The conidia, with the contained zoospores, are also carried through the air in millions by the wind; they are so lightly attached to their supporting stems and so extremely small and light, that the faintest breath of air wafts them away. Insects and other creatures also carry the conidia from place to place. The flies which alight on potato plants carry off hundreds of conidia on their bodies. If a bird drops in a field of diseased potatoes, the fluttering of its wings will disperse millions of the conidia of the fungus of the potato murrain into the air. The same phenomenon occurs when a dog or other animal runs amongst diseased potato plants. When the conidia or zoospores burst and germinate, the threads which emerge are corrosive or putrefactive. To such an extent is this the case that the spawn is said to be capable of piercing or boring through the cuticle of the leaf from within or without, regardless of the natural openings or stomata, and even of piercing the bark of the stem or the tuber itself.

The fungus of the potato disease generally attacks the leaves first, and, as the leaves produce successive crops of fungus growth, the disease quickly spreads to the leaf-stalks, from the leaf-stalks to the chief stems, and from the stems to the tuber. Sometimes a week or two elapses

before the tubers are reached by the putrefactive spawn of the fungus, but in other instances the attack is so sudden and so highly destructive that the whole of the potato plants above ground in a large field will be destroyed in a day or two. The disease doubtlessly starts at first from a few centres only; there it remains for a brief time more or less unobserved. The fungus, however, possesses such wonderful powers of spore production and rapid growth, especially when the air is moist and the temperature ranges from 60° to 70° Fahr., that in a few days one fungus growth will become ten thousand. This growth goes on in a constantly increasing *ratio* until at length the great flood of disease seems to almost suddenly cover the potato fields. When the attack is not violent it is obvious that a good plan is to remove all the tainted potato stems and foliage before the spawn reaches the tubers; but, on the other hand, if the stems are removed before the tubers are ripe, injury must accrue to the crop, as the starch which is subsequently stored up in the tubers is formed in the leaves. Still, it is better to have a poor or partial crop than none at all. Some cultivators advise the growing of more early ripening potatoes, as such varieties now commonly escape the murrain; but there can be little doubt that if a change could be brought about in the general habit of the potato plant it would be followed by an exactly corresponding change in the habit of the parasite. Late ripening varieties are, moreover, wanted, and their cultivation cannot be dispensed with.

When the fungus spawn reaches the tuber it decomposes the cells and corrodes the starch. In bad cases the tubers are soon reduced to a mass of putrefaction. In mild cases the spawn of the fungus hibernates and becomes perennial, as was first pointed out by the Rev. M. J. Berkeley in vol. i. of the *Journal of the Royal Horticultural Society* for 1846. Mr. Berkeley writes (p. 26) in reference to the fungus growing from ripe, harvested,

apparently sound, but really diseased tubers: "It should seem certain, then, that the mycelium or elements of the fungus must have pre-existed in the tuber, and, as it uniformly springs from the decayed spots, that it has itself caused the decay. But here a difficulty arises from the great obscurity, or, as some say, the total absence of mycelium in an early stage of the disease. I have satisfied myself, however, of its existence in some cases, but not uniformly." Again, at p. 28, he writes: "On examining the cuticular cells of a young tuber, with a view to ascertain the changes which occur in the process of greening, I found evident traces of mycelium within them." In the same paper Mr. Berkeley refers to the perennial mycelium of corn mildew. In the *Outlines of British Fungology*, p. 42, Mr. Berkeley writes: "Spawn . . . may exist for years without producing fruit . . . whether it runs through soil or decaying substances, or amongst living tissues, whether without or within their walls." Professor de Bary was no doubt unaware of these published observations when he wrote for the *Royal Agricultural Society*, vol. xx. p. 265, 1876, that he was perhaps the first to point out the presence of perennial mycelium in the potato in 1863. No vegetable growth is more common and well known than perennial mycelium; indeed, with very few exceptions, the spawn belonging to all fungi must at times be perennial. Although perennial mycelium has a far stronger hold on life than have simple spores or conidia, it must not be imagined that perennial mycelium always survives after an unusual amount of heat, cold, or moisture. In the same way as mushroom spawn often dies in the "bricks" of the nurseryman, so the perennial mycelium perishes in the invaded tuber of the potato. In examining diseased potatoes in the winter and spring it is common to find the mycelium dead, and if such diseased potatoes are planted a perfectly sound crop will be the result. In the *Gardeners' Chronicle* for 24th January 1874, we have re-

corded a number of curious experiments made with diseased potatoes. In those experiments it is shown that not only will diseased tubers sometimes produce perfectly sound plants, but that slices of diseased tubers, inserted within the substance of sound ones at the time of planting, will, in some instances, have no ill effect, but that the roots of the sound plant may grow in the putrid remains of the diseased one and still remain untainted. If the perennial mycelium is alive, the result is generally, but not invariably, different. The common mushroom spawn, as sold by nurserymen in "bricks," the white fungus threads we everywhere see when the earth is upturned, and the white felt so commonly noticed amongst fallen leaves, is perennial spawn. The spores of fungi are so extremely delicate that a slight variation of heat, dryness, or moisture often destroys them at once; but when spores have once germinated and produced spawn, this spawn does not so readily perish, but may rest for a long time in a hibernating state. This is proved in the case of the familiar fairy-rings of our lawns and pastures, which sometimes are not seen for many years, as the subterranean spawn is awaiting suitable conditions of warmth and moisture to cause it to produce the perfect fungi.

Here we must not forget that the virus of the disease may exist in some form which has not yet been detected by our microscopes. Before the higher powers of the microscope were used no one suspected the presence of motile zoospores with vibrating cilia; and if we could use still higher powers, it is not unreasonable to imagine that some other condition of the parasite, at present quite unknown to and unsuspected by us, might be brought to light. The fungus may exist in inconceivably fine dust-like particles, or in the condition of a mucous fluid. Because we are acquainted with a certain number of curious facts regarding fungi, it does not follow that we know all. We have long suspected that the virus of this

and many other fungi may exist in inconceivably small and perhaps Amœboid particles.

The resting of the mycelium in a state of hibernation through the winter may, perhaps, sometimes account for the reappearance of the disease the next season; for it has been known, since Mr. Berkeley pointed it out in 1846, that a broken or cut surface of a diseased potato will, if the mycelium is alive, give rise to the potato fungus at any time of the year on the cut potato being exposed to an atmosphere suitably warm and moist. It is obvious that, if the potato disease is annually reproduced by diseased tubers containing perennial mycelium, the disease must invariably begin in the seed-tuber and ascend the stem; but it is known by experience that in the vast majority of instances this is not the case, but that the disease first invades the leaves.

Flowering plants have three familiar modes of increase. One is by suckers, runners, or underground stems; these runners are roughly comparable with perennial mycelium. A second is by buds or bulbils, at times very common in the axils of the leaves of some lilies; these may be compared with the conidia or bud spores of fungi; and a third is by the reproductive organs, or stamens and pistil. Reproductive organs of a like nature, as far as sex is concerned, are known in fungi, and they are potential to and extremely common, well marked, and easily seen in the genus *Peronospora*, to which the potato fungus belongs.

The organs belonging to *Peronospora infestans*, Mont., as far as we have at present described them, have been distinctly asexual, or without sex; no male and female organs answering to the stamens and pistils of flowering plants have yet been referred to.

Mr. Berkeley as long ago as 1846 described and illustrated, from materials furnished to him by Dr. Montagne, what he believed to be an oogonium,—an organism which may be compared with an ovule or unimpregnated egg, and its oospore, or resting-spore condition, which is more or less

comparable with the impregnated ovum, or fertilised seed; but it unfortunately happened that from 1846 to 1875 no one saw the bodies again as originally described by Messrs. Montagne and Berkeley. This failure may have arisen from bad searching or from searching at the wrong time, or, as we believe, in wrong material, through imperfect knowledge; it may partly have arisen from the fact of the oogonia being exactly the same in size with the cells of the potato leaf. Whatever the reason may have been, we at length saw these bodies again in 1875 within the leaves of badly diseased potatoes sent to us from the garden of the Royal Horticultural Society at Chiswick. The sexual organs are illustrated at S, T, U, and V, Fig. 127. As we were, at the time of the discovery, familiar with Mr. Berkeley's writings and views, we instantly perceived, on looking at these growths for the first time, that we had before us the bodies first detected by Dr. Rayer, Chief Physician of the Hôpital de la Charité at Paris; described by Dr. Monatgne, and referred by Mr. Berkeley to *Peronospora infestans*, Mont.

CHAPTER XXXVI.

POTATO DISEASE, II.

Peronospora infestans, Mont.

ITS PASSIVE STATE.

We will now closely examine the bodies found in spent potatoes by Dr. Rayer, illustrated by Dr. Montagne in 1845, and described by the Rev. M. J. Berkeley in vol. i. of the *Journal of the Royal Horticultural Society*, 1846.

Dr. Montagne termed the bodies discovered by Dr. Rayer in the intercellular passages of potatoes, *Artotrogus hydnosporus*. The generic name is derived from the Greek *artos*, bread; and *trogo*, eating or consuming, and bears reference to the power of the fungus in consuming the nutritious material of the tuber; the name shows that Dr. Montagne suspected the true nature of the fungus. *Hydnosporus* indicates that the spores resemble the fungus named *Hydnum*, which has its fruiting surface covered with spines or prickles; *Hydnum* is from the Greek *hudnon*, a word used by Theophrastus to denote a truffle. The specific name is somewhat misleading, as it was only meant to refer to the *mature* spores, as is proved by the writing on Dr. Montagne's original drawing, see page 84; and the description of Mr. Berkeley's plate, *Journal of the Royal Horticultural Society*, 1846, p. 34. In infancy *Artotrogus* is smooth spored. No phenomenon is better known in fungi, as in *Cystopus* and the *Gasteromycetes*, than a smooth oogonium or spore becoming warted or spinulose with age; and Mr. Berkeley, in the volume above quoted, from Dr. Montagne's examples,

figures both the smooth and echinulate form on the same plate. Plain and echinulate spores are produced on the same plant in some *Saprolegnieæ;* and Dr. Max Cornu maintains that the *Saprolegnia asterophora* of De Bary is merely the warted form of *Achlya racemosum,* Hildb. By the courtesy of the Rev. M. J. Berkeley, we have had an opportunity of carefully examining the original examples found by Dr. Rayer, and described by Dr. Montagne ; and we have no hesitation in stating that they are in every way the same with the bodies found by us on the mycelium of *Peronospora infestans,* Mont., in 1875. It is useless to reproduce Dr. Montagne's illustration from vol. i. of the *Journal of the Royal Horticultural Society,* or to engrave his preparations, as they agree precisely with the illustrations made from fresh specimens, and engraved in the following pages. Dr. Montagne's examples represent fertilised semi-mature oospores, most of the specimens have a smooth external surface, but some of the more mature specimens are spinulose ; and for this reason Dr. Montagne doubtlessly selected the specific name *hydnosporus.*

Dr. Rayer, then, was the first person who in 1844 or 1845 detected resting-spores in the genus *Peronospora;* and the Rev. M. J. Berkeley was the first person who pointed out the fact of *Peronospora* being an oospore-bearing fungus. Mr. C. Edmund Broome next found the *Artotrogus* of *Peronospora parasitica,* Pers.; and Mr. Berkeley again pointed out its true nature in the *Gardeners' Chronicle* for 1854, p. 724. In 1845 Tulasne made great advances in our knowledge of the oospores of *Peronospora ;* and his observations were laid before the French Academy in 1854, and published in *Comptes Rendus* for 26th June of that year. In 1855 Dr. Caspary published still further advances in the *Monthly Transactions of the Royal Academy of Berlin ;* he there illustrates the oogonia or *sporangia,* as he terms them, of *Peronospora Hepaticæ,* Casp., and *P. densa,* Casp. Dr. Caspary's observations were, he says, made

before he was aware of Tulasne's discoveries. Professor De Bary of Strasbourg, in 1863 (*Ann. des Sc. Nat.*, ser. iv., vol. xx.), made still further progress in detecting the oospores or resting-spores of *Peronospora.*

Oogonia or immature resting-spores are illustrated, growing from the mycelium of the potato fungus within a potato leaf, at S, T, U, and V, in Fig. 127. At S an oogonium is seen intercalated within a thread of the potato fungus; at T and U the oogonia are terminal, each with a second smaller body, termed an *antheridium*, attached; and at V another intercalated example is shown.

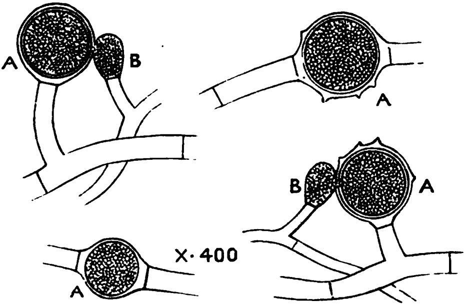


FIG. 130.
The sexual organs, or oogonia and antheridia of *Peronospora infestans*, Mont. Enlarged 400 diameters.

These bodies belong to the *Artotrogus hydnosporus* of Montagne. As the magnification of 100 diameters is insufficient to distinctly show the nature of these oogonia, we have enlarged them to 400 diameters in Fig. 130. In each of the four examples A represents an *oogonium* or cell in which a female reproductive body, termed an oosphere, is formed; and each of the two bodies at BB is termed an antheridium, or cell which contains the male reproductive material. The oogonium may be roughly com pared with a pistil in flowering plants, and the antheridium

compared with the anther and its pollen. In the process of growth the antheridia naturally come into contact with the oogonia, just as an anther may touch a stigma. When this contact takes place the antheridium projects a fine tube into the walls of the oogonium till the oosphere within is touched and pierced. Some of the vital material from the antheridium then very slowly passes through the tube, mingles with the protoplasm within the oosphere and fertilisation, and the formation of an oospore is the result. Just as in flowering plants an ovule becomes a seed after fertilisation, so the oosphere becomes an oospore or resting-spore after the contact of the antheridium with its contents.

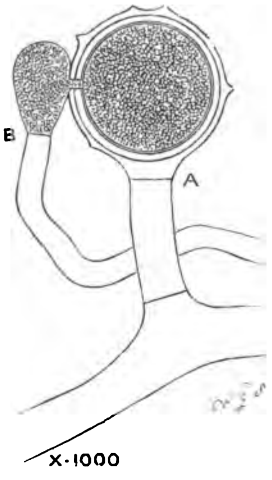


FIG. 131. — *Peronospora infestans*, Mont. Oogonium and antheridium. Enlarged 1000 diameters.

An antheridium in contact with an oogonium is farther enlarged to 1000 diameters in Fig. 131, to more clearly show the beak or fecundating tube in the act of piercing the oogonium and its contained oosphere. By careful watching under the microscope, the granular protoplasm from the antheridium may be seen to pass very gradually into the oosphere. The oogonium originates by the contained protoplasm in the mycelium congregating in certain positions, generally at the ends of, or within the mycelial branches, the end of the branch becomes distended with vital material, and a bladder is formed, which is speedily cut off by a septum or joint, as at A, Fig. 131. In many in-

stances (but not in all) the antheridium springs from the same thread as the oogonium, and close to the oogonium itself; here the protoplasm again forms a smaller bladder-like expansion, which soon becomes (as in the oogonium) separated from the supporting thread by a septum, as at B, Fig. 131.

After fertilisation the oogonia readily fall from their supporting threads, just as simple spores drop from their supports, or as seeds drop out of seed-vessels. There is no further need of connection with the parent stem, so the resting-spores, like seeds, are set free.

It follows from this fact, that unless the oogonia are sought for at the precisely right time, they will not be seen upon the supporting threads, which soon perish. A notable instance of this phenomenon occurs with the *Peronospora* of the lettuce. In this species myriads of oogonia are formed in dense conglomerated masses, Fig. 126; but they are no sooner formed than they are cut off from their supporting mycelium by septa, and then the mycelium perishes. Nothing is more common than to see large numbers of oogonia and no mycelium. The case is similar with free seeds or seed-vessels where the old tender flower remains have perished.

Every competent botanist who has sought for these potato oogonia since 1875 has found them. Mr. C. B. Plowright found both the smooth and spiny form in the summer of 1876, as described and illustrated in the *Gardeners' Chronicle* for 29th July 1876. At the present time both oogonia and ripe oospores, not only of the potato fungus, but of various other species of *Peronospora*, may be purchased from the Rev. J. E. Vize.

In 1875, when our observations were made, great attention was directed towards the potato disease, as it not only occurred with great virulence, but it appeared unusually early in the season. In that year the leaves of the potatoes were the first organs attacked, and old observers said that no such curled and distorted leaves had

been seen for many years. We were, therefore, naturally desirous of making a close examination of them. Some of the earliest examples were sent on to us, and as we were well acquainted with the potato fungus and its habit of growth, we placed a series of infected leaves—one over the other, like the leaves of a book—in a saucer. To keep the leaves constantly and naturally moist, we placed a very little water in the saucer, and this water just touched the points of the leaves. The saucer was next slightly tilted, so that the water might remain at one spot, and the leaves slowly and naturally absorb it. The saucer with the leaves was then placed under a bell-glass, the bell-glass was covered with a cloth, and the whole kept in a warm room. The potato leaves were then, as we thought, in a favourable position for the full development of the *Peronospora*, with no chance of a sudden check from too much dryness or cold. At that time we had no idea whatever in the direction of the artificial production of oospores or resting-spores; but on examining the potato leaves as they gradually fell into decay, we were surprised to see numerous examples of what we believed to be *Artotrogus* attached to the *Peronospora* mycelium. At first the examples were few in number, but at length they were abundant. Soon after our results were published, Mr. C. Edmund Broome, M.A., F.L.S., of Batheaston, repeated the experiments, and obtained results precisely the same with ours. Ultimately Mr. Broome went over the ground a second time, and again obtained like results; at length, many other observers repeated the experiments, and always with the same issue.

A very successful plan for procuring resting-spores, and one which we have not known to fail, was last year suggested to us by our friend Mr. A. Stephen Wilson. A number of leaves must be taken from potato plants invaded by *Peronospora infestans*, Mont.; these leaves must be slightly moistened and placed one over the other near the top, inside a bell-glass; the bell-glass must then be put

mouth downwards on any flat surface, and a saucer of water placed underneath to keep the air humid by evaporation. The result invariably is, that the *Peronospora* mycelium within the potato leaves gives rise to an enormous number of oospores or resting-spores; and as the leaves gradually decay, the decayed material swarms with the *Artotrogus hydnosporus* of Montagne,—the resting condition of the potato fungus.

During the early autumn of 1875 another important fact in regard to the potato fungus came to light. On making a rigid examination of every part of diseased potato plants for oospores, we found them in great abundance in the old exhausted seed tubers. In every other part of the potato plant the oogonia were rare; but in the old sets the oogonia sometimes swarmed in myriads. The explanation of this fact may be that the tubers were in this instance planted with the perennial mycelium of the potato fungus in their tissues. As this mycelium on starting into growth could not produce conidia, being underground, it spent itself in the tuber by a vast production of oospores. There is no more certain position for lighting on large colonies of resting-spores than in the old exhausted seed tubers belonging to potato plants destroyed by the *Peronospora*, or in the old diseased and damaged tubers that are left in the field to rot, or are incorporated in dung heaps as manure.

It is curious that at the very time when we were making the above observations, Dr. Sadebeck of Berlin found a parasite, named by him *Pythium Equiseti*, first upon *Equisetum arvense*, L., and afterwards (as he at first thought) upon living potato plants near Coblenz. Whether the *Pythium* upon the *Equisetum* was the same as the parasite upon the potatoes is uncertain, as Professor Sadebeck could not transfer the parasite from one plant to the other, neither could we do so on repeating his experiments. Our impression is that the parasites are distinct. *P. Equiseti*, Sdbk., was described and illustrated by us,

from nature as British in the *Gardeners' Chronicle* for 20th May 1876. It is extremely common in this country. Dr. Sadebeck found his second fungus in the possession of the living potato plant, for he wrote—(*Untersuchungen über Pythium Equiseti. Beiträge zur Biologie der Pflanzen.* Breslau, 1875):—"In the first days of July 1875 I saw at Metternich, not far from Coblenz, a potato field which to all appearance was affected with the murrain; a closer examination, however, showed that the signs of the disease were traceable almost entirely to *Pythium Equiseti.* The anticipated *Peronospora* was not found on any of the plants examined; on the contrary, the *Pythium* was discovered in a great number of plants and in all parts of the plants." In a criticism published in the *Journal of Botany* for March 1876, it was stated, in reference to this part of the subject, that it had "lately been attempted to connect this fungus (*Pythium Equiseti*, Sdbk.) with the oospores of *Peronospora infestans.*"

In the same year Mr. James Renny, a member of the Scientific Committee of the Royal Horticultural Society, was also studying a *Pythium* which he believed to be new, and which was provisionally named by him *P. incertum.* This was exhibited at the Royal Horticultural Society and Linnean Society, and according to the *Journal of Botany*, 1876, p. 156, Mr. Renny considered his *P. incertum* to be the same with the oospores found by us. *P. incertum* was engraved by us in the *Gardeners' Chronicle* for 1st July 1876, and we need hardly say is totally different from *Artotrogus.*

Dr. Max Cornu, who at this time had our preparations before him, said they reminded him of *P. proliferum*, De Bary, another different fungus; for an illustration of this see *Gardener's Chronicle*, 1st July 1876. He also thought they looked like the *Myzocytium* of Schenk.

At the time when these investigations were going on, Professor de Bary himself was, by a commission received from the Royal Agricultural Society of England, making

observations upon the potato fungus for that Society. It appears that Professor de Bary also lighted on what he considered to be a fourth new species of *Pythium*, and first seen by him in potatoes in 1874 and 1875. This fungus the professor named *P. vexans*, and an original description, with an illustration, is given in the *Journal of the Royal Agricultural Society* for 1876, vol. xii. p. 252. In 1881, in the *Beiträge zur Morphologie und Physiologie der Pilze*, Professor de Bary has compared *Artotrogus* with two other species of *Pythium*, both new, and named by him *P. micracanthum* and *P. megalacanthum*. He says the former may perhaps be *Artotrogus*.

It does not specially concern us here what these six species of *Pythium* are, or whether they are new or distinct from each other or not. *P. proliferum*, D.By., is probably distinct, but we can see no difference between *P. incertum*, Ry., *P. Equiseti*, Sdbk., and *P. vexans*, D.By. They are simply referred to here because some writers have at times confused the potato oogonia seen by us with one or other of these six organisms.

As *P. vexans*, D.By., appears to us to be the same with *P. incertum*, Ry., and *P. Equiseti*, Sdbk., we here reproduce at Fig. 132 the original illustration altered to 400 diameters for comparison with the *Peronospora* oogonia given to the same scale in Figs. 130, 134, 135, and 136. It will be noticed that the *Pythium* is smaller in all its parts, and that the oogonia AAA are invariably non-echinulate. The mycelium is thick and septate in the *Peronospora*, and non-septate and very thin in the *Pythium*.

The great point of difference is this: the *Pythium* oogonia will, as soon as formed, and within twenty-four hours germinate in water. In germination, a tube is sometimes produced, as at B, Fig. 132. In other instances when the oospores of *P. vexans*, D.By., are kept for a few days so as to ensure their complete maturity, they germinate by ejecting a small transparent bladder, as at C; the proto-

plasm from the oogonium now pours into the bladder and becomes quickly differentiated into six or eight little zoospores; the bladder then dissolves, the zoospores swim away, and the short-life cycle of the *Pythium* is completed.

The phenomenon of speedy germination is foreign to *Artotrogus* and the oogonia of *Peronospora infestans*, Mont. The latter bodies do not remain transparent or germinate at once; on the contrary, they hibernate for at least ten months, and during this long period of rest they increase in size, become warted or echinulate, and attain a rich palish-brown colour.

We will now leave the potato fungus as seen in a

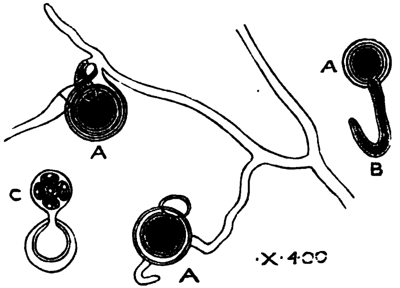


FIG. 132.
Pythium vexans, D.By. Enlarged 400 diameters.

living potato leaf and take a fragment of a dead leaf, one that has been destroyed by the *Peronospora*, such as may be seen in fields and gardens in September, or, if preserved with care, such as may be kept on a garden-bed till the following June. A fragment of such a potato leaf is illustrated in Fig. 133, enlarged, like Fig. 127, to 100 diameters. The upper surface of the leaf is shown at A, the lower surface with two stomata at BB, and a small hair belonging to the leaf is seen at C. Nearly all the mycelium of the potato fungus has vanished; a fragment

only, in a hibernating, septate state, is seen at D. The transparent oogonia of the summer have now become brownish ripe oospores or winter resting-spores of a larger size. Six resting-spores are shown in the illustration,—

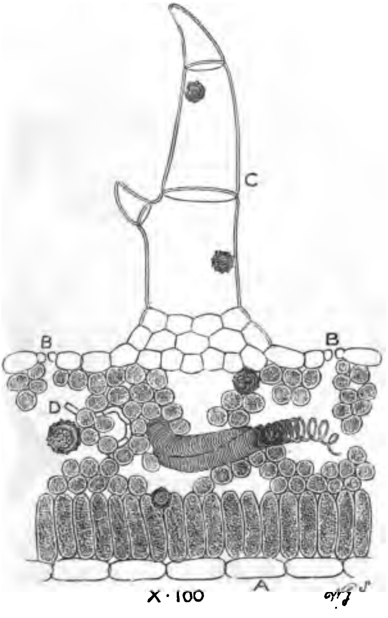


Fig. 133.
Section through a fragment of old potato leaf, with resting-spores or oospores, of *Peronospora infestans*, Mont., *in situ*. Enlarged 100 diameters.

two in the transparent leaf hair, three in the intercellular spaces of the leaf, and one inside a spiral vessel, in which position it is extremely common to find them.

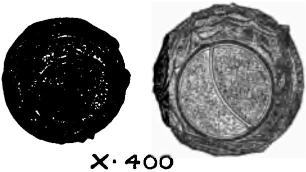
The perfectly mature resting-spores are best seen in the

remains of old rotten tubers left in the fields from the previous year, and commonly seen on the ground and about dung-heaps and hedge-sides in March and April. A section through a fragment of decayed tuber is shown,

FIG. 134.
Section through fragment of diseased tuber of potato, with starch granules and oospores of *Peronospora infestans*, Mont., *in situ*.
Enlarged 400 diameters.

enlarged 400 diameters, at Fig. 134. One large oospore is seen in an intercellular space, another in a cell amongst the granules of damaged starch, and a third within the

coils of a spiral vessel. In colour the oospores are of a beautiful palish-brown tint, like brown sherry; sometimes they are darker. The protoplasm within is at maturity no longer seen as a loose, transparent, finely granular mass; it has become compact and slightly convolute, as illustrated —ready under favourable conditions to burst the walls of the oospore, and, by producing a germ-tube, reproduce, after nearly a year's rest, the fungus of the potato disease. It may be observed here how totally different this condition of the fungus is from *Pythium vexans*, D.By., engraved to the same scale in Fig. 132. An original microscopic slide of *P. vexans*, D.By., is preserved in the Department of Botany, British Museum, South Kensington;



X·400

FIG. 135.
Peronospora infestans, Mont.
Oospores of large size on slides A and B in the British Museum.
Enlarged 400 diameters.

it may there be compared with true potato oospores furnished by the Rev. J. E. Vize and ourselves. Sometimes oospores of the potato fungus attain large dimensions, as in Fig. 135. The right-hand example is on slide A, the left-hand on slide B, in the British Museum.

On an examination of a large number of resting-spores it will be found that the convolute mass of protoplasm within, though generally in one coil, may at times be in two or even three distinct portions, which on germination, will produce one, two, or three germ-tubes, as shown at A, B, C, Fig. 136, enlarged 400 diameters; in other instances the interior mass becomes differentiated into zoo-

spores which escape, as at DD, and speedily come to rest and germinate, as at E; the germinal threads from oospores and zoospores alike, when placed either on the foliage or tubers of potatoes and kept uniformly moist and warm,

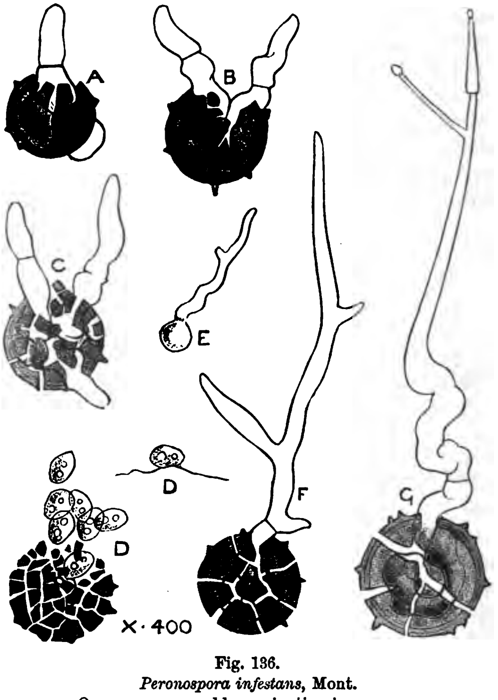


Fig. 136.
Peronospora infestans, Mont.
Oospores a year old germinating in summer.
Enlarged 400 diameters.

soon give rise to the fungus of the potato disease, and cause discoloured patches of decomposition as the growth proceeds. This condition of the fungus was described

and illustrated by us in the *Gardeners' Chronicle* for 8th July 1876. Germinating resting-spores in a more advanced state of growth are illustrated at F and G. On germination, the walls of the oospore break up into many pieces, sometimes into fine dust. The first sign of germination is generally shown by the walls of the oospore breaking into two hemispheres, or into three or more pieces. In some instances more than one oospore exists within the oogonium, and all oospores may at times produce zoospores, as in *Cystopus*. In the *Gardeners' Chronicle* for 8th July 1876 a full description, with numerous illustrations of germinating oospores, will be found.

Our experiments were at first objected to on the ground that all the species of *Peronospora* were, it was said, so sensitive to decay that they invariably perished with the death of the supporting plant. This statement is now known to be erroneous, and the resting-spores of the *Peronosporeæ* are at this time always sought for, and almost invariably found, in material which has been more or less destroyed by the mycelium of the invading parasite. This decayed material is obviously the only material in which ripe oospores can be expected to occur. Every part of the fungus, except the oospores, generally perishes with the supporting plant; the oospores or resting-spores are left alive upon or in the ground where potato material has decayed, and in this position the oospores germinate in June and produce the first conidia of the season. Such of the conidia as are blown from the ground or from decaying potato refuse on to potato plants, or certain allied plants, produce disease; such as fall in unsuitable positions perish. The progress of the disease is, therefore, necessarily at first extremely slow: it only progresses with rapidity after the living potato plants are thoroughly invaded.

We have secured potato oospores direct from the ground by observing water filtered through earth on which diseased potato material has been allowed to decay.

The best time for seeing the reproductive organs of

Peronospora infestans is in August and September. A potato plant should be selected that has been destroyed or reduced to putridity by the disease. This plant should be taken up with a fork, and the exhausted seed tuber from which the plant has arisen carefully sought out. This seed tuber, or what is left of it, may be frequently found reduced to a sort of transparent jelly, and this jelly-like mass will in many cases be found swarming with the living oogonia and antheridia of the potato fungus. The fungus has attacked the leaves and proceeded downwards by the stems into the seed tuber from which the plant originally arose, and there, having run its course, it has produced resting-spores for the invasion of the following year's crop of potatoes. It is much less common to find resting-spores in the hard new tubers even when discoloured by disease; still it is quite possible to find them even in new potatoes. Ripe resting-spores of the potato fungus may be found with great ease in the spring and early summer, in the fragments of diseased and decayed potatoes picked up in the fields or about manure and refuse heaps by hedge sides.

A germinating resting-spore may be compared with a germinating seed of dodder. The dodder has enough nourishing material stored up within its outer integument to support an infant dodder plant for a short time. If no suitable host plant is near, the young dodder perishes. The first fruiting branch from a germinating resting-spore of the potato fungus is in an exactly similar condition, for, unless the spores or conidia are aided by the wind to reach a potato or some other suitable plant, the first-produced conidia perish at once. The resting-spores of the potato fungus germinate in and upon the ground at the precise time of the year when the potato plant is in the best condition for infection. Habits of this nature are extremely common and well known amongst parasitic fungi.

We have as far as possible in this work avoided con-

troversial matter, only referring to disputed opinions and deductions by giving without bias the views held on both sides. Nothing is more damaging to the position of science than disrespectful and hasty criticism and animadversion. It is, however, necessary to inform our readers that our views, as here advanced, in reference to the nature of the oospores of the potato fungus and of *Artotrogus*, have been criticised by Professor A. de Bary of Strasbourg, in the *Journal of the Royal Agricultural Society of England*, second series, vol. xii. p. 239, 1876.

Professor de Bary's objections to our views were the following :—

1. He disapproved of our comparison of the potato fungus oospores with the oospores of *Protomyces;* see our notes under *Protomyces macrosporus*, Ung., in this work.
2. He could not accept our drawing as illustrating the potato fungus at all, as it presented an important difference, he said, from the real *Peronospora infestans*, Mont.
3. Our assumed "oogonia," "antheridia," and "oospores," he said, were "bladders," and did not belong to the potato fungus.
4. The mycelium, he said, was wrong, as the threads bearing "oogonia" and "antheridia" were only shown in *local* and not in anatomical relation with each other.
5. He objected to the septa shown by us in the mycelium.
6. He objected to the *habitat* we gave for the oospores, *i.e.*, in decayed potato material.
7. He stated in reference to *Artotrogus* that there was no evidence of its nature as an oospore.
8. That there was no reason for considering it as belonging to the potato fungus.
9. That the smooth form of *Artotrogus* was a different fungus from the echinulate one found with it.

10. That the mycelium of *Artotrogus* was not septate, as illustrated by us, but that it was like the mycelium of *Pythium vexans*, D.By., *i.e.*, in one continuous piece without septa.
11. That our "bladders" were more like the oospores of the *Peronospora* of the vine or some *Pythium*.

Many other minor objections were advanced. Replies will be found in *Nature* for 27th April and 25th May 1876, and in various numbers of the *Gardeners' Chronicle* for 1876. A report from the pen of the Rev. M. J. Berkeley will be found in the *Gardeners' Chronicle* for 1st April 1876, p. 436. Our original illustrated papers were published in the *Gardeners' Chronicle* for 17th and 24th July 1875. Micro-photographs from nature, of potato oogonia, and antheridia were published by us in the *Quarterly Journal of Microscopical Science* for October 1875. The first sketches made by us are at Kew, and the more carefully finished drawings are in the British Museum. A moderate, independent, and just *resume* of the whole subject was published by W. Peard, M.D., LL.B., in the *Journal of the Bath and West of England Society and Southern Counties Association*, vol. viii., third series, 1877.

For the discovery of the reproductive organs and oospores of *Peronospora infestans*, Mont., the Royal Horticultural Society of England awarded us their Knightian medal in gold.

Some time prior to 1881 Professor de Bary changed his views in reference to the nature of *Artotrogus*, as in the latter year he agreed with us in illustrating and describing the organism as a true oospore, as supported on septate mycelium, and with an antheridium in "local" and not "anatomical" relation to the thread of the oogonium, precisely as we originally illustrated it.

The accompanying illustration, Fig. 137, enlarged 600 diameters, is copied from the *Beiträge zur Morphologie und Physiologie der Pilze*, 1881, and it represents, from pl. 1,

Artotrogus from Professor de Bary's own hand; it shows the septate mycelium at AAA, the supporting thread of the oogonium at B, and the distinct supporting thread (not anatomically connected) of the antheridium at C. At D the antheridium has projected a fecundating tube through the outer wall of the oogonium to the oosphere within. Professor de Bary found these bodies in *Lepidium*, so they cannot be the true *Artotrogus hydnosporus*, Mont., which is borne only on the mycelium of *Peronospora infestans*, Mont. They are the second form of *Artotrogus*, peculiar to cruciferous plants, as first

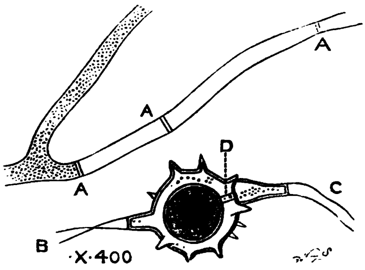


FIG. 137.
Artotrogus, as illustrated by Professor De Bary in 1881.
Enlarged 400 diameters.

detected by Mr. C. Edmund Broome, M.A., F.L.S., of Batheaston, Bath, in 1849, and referred to *Artotrogus* by Dr. Montagne. They grow upon the mycelium of *Peronospora parasitica*, Pers., and are the oospores or resting-spores of the putrefactive fungus of the cabbage tribe, as pointed out by the Rev. M. J. Berkeley in the *Gardeners' Chronicle* for 1854, p. 724. They are illustrated, from nature, in this work in Figs. 31, 37, and 38.

No agricultural subject is more difficult to approach than the possible curative or preventive treatment of the potato disease. Cure, we may say, is utterly impossible,

but prevention or palliation may be considered fairly within reach, and this prevention can only be attained by skilful culture and perfect winter storage.

Sometimes growers keep their potatoes in enormous underground heaps called "pies;" in these positions the tubers frequently heat and rot; in other instances diseased potatoes are interbedded in dunghills, or dug into the ground; in all such cases the best means have been taken for successfully propagating the disease. From all such positions many millions of conidia of the potato fungus are dispersed each June, whose special mission is to devastate potato crops. The warmth and moisture of "pies" and manure-heaps are the exact conditions required by resting-spores for their maturation.

To prevent the annual recurrence of the potato murrain it is in the highest degree necessary to destroy the material which is undoubtedly swarming with myriads of disease germs. This destruction should be effected by burning, or, where burning is not practicable, deep burial might be resorted to. No more fatal mistake can be made by potato growers than leaving dead stems, leaves, and tubers about in their fields, especially after a potato crop has suffered from disease.

When cut sets are used at planting, the cut surface should perhaps be allowed to heal or dry before planting, or, if this is not convenient, the cut surfaces might be quickly passed over a hot iron. It frequently happens when diseased sets are used that the produce grows in a healthy manner, with no trace of the murrain. There can be little doubt of the existence of perennial spawn in some of these examples, if not of resting-spores; but in some instances it would appear that neither spawn or spores work much mischief direct from the seed tuber when buried. In some instances both mycelium and oospores must be dead.

Any cure of the murrain in invaded potato plants is quite hopeless, for in this disease the substance of the

potato tuber is decomposed, and it is impossible to replace rotten tissues with sound. With the object of prevention in view, hardy varieties which have not exhibited disease should be selected and reselected. They should be grown where possible in well-drained dry soil, and mineral manure should be used. As darkness, heat, and humidity are highly favourable to the growth of the *Peronospora*, all potatoes should be stored in perfectly dry, airy places, in positions where light is not entirely excluded. Potatoes should never on any account be stored in heaps or in the damp holes in the ground termed "pies."

During the last year or two great attention has been directed to the potato plant and its treatment under disease, chiefly by Mr. J. L. Jensen of Copenhagen, and Mr. C. B. Plowright, M.R.C.S., in the pages of the *Gardeners' Chronicle*, and more lately by Mr. J. G. Baker, F.R.S., in the *Journal of the Linnean Society*, and to these communications it is necessary for us to advert.

The paper by Mr. J. G. Baker, F.R.S., F.L.S., written at the request of Earl Cathcart, in the *Journal of the Linnean Society* ("Botany," vol. xx. p. 489), is called "A Review of the Tuber-bearing Species of *Solanum*." Mr. Baker reviews the species and varieties of tuber-bearing *Solanum* geographically, beginning under Chili with—1. *Solanum tuberosum*, L.; 2. *S. etuberosum*, Lind.; 3. *S. Fernandezianum*, Phill.; 4. *S. Maglia*, Sch.; and 5. *S. Collinum*, Dun. Brazil—1. *S. Commersoni*, Dun., and its var. *S. Ohrondii*, Carr. Peru, Bolivia, Ecuador, and Colombia—1. *S. tuberosum*, L.; 2. *S. immite*, Dun.; 3. *S. Colombianum*, Dun.; 4. *S. Valenzuelæ*, Pal. (*S. Maglia* Sch.) Mexico—1. *S. verrucosum*, Sch.; 2. *S. suaveolens*, K. and B.; 3. *S. stoloniferum*, Sch.; 4. *S. demissum*, Lind.; 5. *S. utile*, Klot.; 6. *S. squamulosum*, M. and G.; 7. *S. cardiophyllum*, Lind.; 8. *S. oxycarpum*, Sch. South-Western United States—1. *S. Fendleri*, A. Gray; 2. *S. Jamesii*, Torr. Of these plants Mr. Baker considers there are only six genuine species in a broad sense, viz.—1. *Solanum*

tuberosum, L.; 2. *S. Maglia*, Sch.; 3. *S. Commersoni*, Dun.; 4. *S. cardiophyllum*, Lind.; 5. *S. Jamesii*, Torr.; and 6. *S. oxycarpum*, Sch. Mr. Baker states that of all known species of *Solanum*, only six produce potatoes, and the remainder propagate themselves by their flowers, fruits, and seeds. In reference to the Mexican *S. demissum*, Lind., Dr. Lindley, in his notes on the wild potato, published in the *Journal of the Royal Horticultural Society*, vol. iii., 1848, says that when grown in England it was attacked by the disease in July, and exhibited the characteristic black blotches in a worse degree than any other in the garden. The runners were also affected. The Mexican *S. cardiophyllum*, Lind., on the other hand, was not attacked by the disease. Dr. Lindley concluded that neither renewal of seed, introduction from foreign countries, or treatment in the earth afford any guarantee against the attacks of the disease. Sir Joseph Hooker has stated that *S. Maglia*, Sch., when grown at Kew, did not yield tubers for the first two years. It has now been grown there for twenty years side by side with the common potato, *S. tuberosum*, L., and maintains its individuality. It does not, however, produce berries. Both plants are natives of Chili; but Mr. Baker points out the very important fact that whilst *S. tuberosum*, L., is a plant of the hills of the interior, *S. Maglia*, Sch., grows in the near neighbourhood of the coast. This is the potato found by Mr. Charles Darwin in the Chonos Archipelago in south latitude 44°, 45°; and Mr. Baker throws out the happy suggestion, and one which we hope will be generally adopted, that *S. Maglia*, Sch., should become popularly known as Darwin's potato, a plant which, as far as climate is concerned, Mr. Baker thinks without doubt is better fitted to succeed in England and Ireland than *S. tuberosum*, L., a plant belonging to a comparatively dry climate. Both *S. Maglia* and *S. Commersoni*, Dun., yield an abundant supply of edible potatoes. Mr. Baker suggests that these two species should be brought into commerce and thor-

oughly tested as regards their economic value, both as distinct types and when hybridised with the innumerable forms of *S. tuberosum*, L.

Mr. Charles Darwin described *Solanum Maglia*, Sch., in the 1835 octavo edition of the *Voyage of the Beagle*, p. 288. He there writes:—"Chonos Archipelago.—The wild potato grows on the islands in great abundance on the sandy, shelly soil near the sea-beach. The tallest plant was 4 feet in height. The tubers were generally small, but I found one of an oval shape 2 inches in diameter. They resembled in every respect and had the same smell as English potatoes; but when boiled they shrunk much and were watery and insipid, without any bitter taste. They are undoubtedly here indigenous. They grow as far south, according to Mr. Low, as latitude 50°, and are called *Aquinas* by the wild Indians of that part." We give an illustration, natural size, of the flowers, foliage, and tubers of Darwin's potato, *Solanum Maglia*, Sch., in Fig. 138 (frontispiece). Sir Joseph Hooker, in writing of this species in the *Botanical Magazine* for May 1884, says the tubers were first sent by Mr. Alexander Caldcleugh from Chili to the Royal Horticultural Society in 1822. Mr. Caldcleugh's tubers were cultivated in manured soil at the Royal Horticultural Gardens, where two plants yielded about 600 tubers of about the size of a pigeon's egg and under, which had, when boiled, the flavour of a common potato. Tubers of the same species were given to Kew in 1862 by Dr. Sclater, F.R.S.,—these were grown in the sandy soil of the pleasure-grounds without manure. Experiments are now being carried out under the auspices of the Royal Agricultural Society to improve the qualities of the potato, especially in its power of resisting attacks of the potato disease, by crossing *S. tuberosum*, L., with its allies, and amongst them with *S. Maglia*, Sch. Sir Joseph Hooker says that *S. Maglia*, Sch., flowers freely every autumn at Kew, and yields watery, scarcely edible potatoes.

Mr. Baker has not seen *S. Commersoni*, Dun., in a living state, but he says that *S. Ohrondii*, Carr., recently described and illustrated in the *Revue Horticole*, 1883, pp. 496-500, Figs. 99, 100, and afterwards adverted to at some length by the horticultural press of this country, is the same plant. Sir Joseph Hooker, in the *Flora Antarctica*, reduces it to a mere form of the common edible potato, *S. tuberosum*, L. Tubers of this plant were lately brought by M. Ohrond, a French naval surgeon, from the island of Goritti, at the mouth of the Rio de la Plata, and grown at Brest by M. Blanchard, gardener-in-chief of the Marine Hospital, who writes as follows :—"From the time of its importation I have cultivated the plant, or rather left it to itself to grow, for it is almost impossible to destroy it when once it has become established in a piece of ground. Each year, at the end of June or the beginning of July, I have collected the tubers; but the rootstock creeps so widely that always plenty have remained in the ground to furnish stock for another year. It is my belief that it would be easy to improve the tubers by simply cultivating them. Already the cultivated tubers are much better than those which I received from M. Ohrond. The wild tubers were scarcely bigger than small walnuts, but some of those of the cultivated plants have attained the size of small hen's eggs. I may add that the tubers are quite palatable, with a taste of chestnuts, but leaving in the mouth a slight flavour of acidity, like that of a potato that has sprouted. My workmen and I have tried them both boiled and baked in the oven; the latter are preferable. As to the hardiness of the plant it is complete—at least here at Brest. During the winter of 1881, when the thermometer fell two degrees centigrade below freezing point, the tubers took no harm, and *up to the present time the plant has not been found to suffer in the least from disease.*"

Mr. Baker thinks that our present method of potato culture unfits the plant to resist disease by exciting the

plant grown in crowded positions, to a large production of tubers. He thinks, in agreement with suggestions often made by writers on horticultural subjects, that the absence of flowers and berries on cultivated potatoes is a proof that the plant is in an unnatural and disorganised condition. Mr. T. A. Knight has shown, in the *Philosophical Transactions* for 1806, p. 297, that the varieties of potatoes which uniformly produce neither flowers or berries may be caused to produce them by preventing the growth of tubers and runners amongst the fibrous roots.

The writings of Mr. J. L. Jensen of Copenhagen, as laid before the horticultural world by Mr. C. B. Plowright, M.R.C.S., have chiefly had reference to what Mr. Jensen has termed "Protective Moulding."

It is a common practice amongst potato growers to earth-up potatoes, usually by driving a plough between the rows. This earthing-up not only helps to support the potato haulms in an upright position in the rows, but it keeps the potato tubers from the light and consequent greening; it obviously keeps the potatoes free from the numerous injuries they sometimes sustain from the attacks of wire-worms, slugs, snails, rabbits, rats, moles, and other animals, and from cracking after exposure to sun, hail, rain, and wind. A potato when scratched, bitten, or bruised, and with its inner substance exposed, is much more liable to the attacks of fungus parasites than examples with the natural armour of a perfectly whole skin. We have shown that the mycelium of the fungus enters the potato plant by the organs of transpiration, and sometimes even pierces the epidermis or bark in its effort to reach the interior. It follows, then, that any injury to the leaves, stem, or tuber, even if the injuries are of the most microscopic proportions, must aid the parasite in its efforts to gain access to the inner tissues of the host. The fact has long been accepted by a large section of potato growers that earthing-up has also a marked tendency to keep potato tubers free from the murrain, even when the

haulms have been completely destroyed by the parasite. A prize essay on this subject by Dr. Jeffrey Lang will be found in the *Journal of the Royal Agricultural Society* for 1858. Dr. Lang experimented to the full depth of a spade or fork, and double ploughed, the potatoes being early earthed-up, with the result that few or none of the potatoes so grown were diseased. Dr. Lang mentions the case of "a man at Whilborough" who on dry days, in order to save his potatoes, instead of digging them up, earthed the stalks up very high, and so effectually saved his crops. "It was observed," writes Dr. Lang, "that no potato covered with more than 3 inches of soil was ever diseased," and "I have seen scores of potatoes dug, but I have never seen or heard of one diseased potato being found 4 inches under the surface of the ground. It will be at once seen—and too much stress cannot be laid on the fact—that the disease is in an exact ratio to the proximity of the tubers to the surface." Dr. Lang also experimented with tubers in the following manner:—Three series were planted three deep, and covered with two-and-a-half inches of soil. On two series diseased potato leaves were placed, and then supplied with water through a fine rose; the third set were covered with a slate. In all three series the under layers of potatoes were found undiseased; all were undiseased under the slate; whilst the upper layers covered with diseased potato leaves were found to be much affected or quite rotten. He ends the essay by saying, "Earthing-up repeatedly with fine earth is the only effectual preventive to the ravages of the disease."

During the last quarter of a century the subject has been frequently adverted to in the horticultural and agricultural papers. In some instances a good result has been recorded, in others a negative one. As commonly practised, the harvest of large tubers is said to be lessened, and in some quarters the extra expense, care, and labour has been greatly objected to. Professor W. G. Farlow, in

the *Bulletin of the Bussy Institution*, part iv., refers to deep planting, which is much the same with earthing-up, and writes, p. 336 :—"Theoretically, it would appear to be an advantage to plant deep, that the tubers may have less chance for being infected from spores which have fallen from the surface. Practically this does not work well, but potatoes planted near the surface do best. However, the plan tried by some cultivators in England, with apparently good result, of hoeing the earth up over a good part of the tops as soon as the rot appears, is worthy a trial."

During the last two years Mr. J. L. Jensen, a gentleman of Copenhagen, has, chiefly through the mediumship of Mr. C. B. Plowright, of King's Lynn, again placed the subject of earthing-up prominently before the agricultural and horticultural public of this country.

Some of Mr. Jensen's views have been opposed by Mr. William Carruthers, F.R.S., the Keeper of the Department of Botany at the British Museum ; by Mr. George Murray, also of the British Museum ; and by ourselves, as contrary to fact, and contrary not only to the experience of botanists, but, what is of more importance, to the experience of practical potato-growers and dealers. Personally, we advocate, and have always advocated, careful earthing-up ; it agrees with the practice approved by many potato growers. That earthing-up is, however, not esteemed by all seems shown by the fact that neither Dr. Lang's suggestions here, or Professor Farlow's in America, have been generally adopted.

Mr. Jensen says a high and sharp ridge of earth should be thrown up round the potato plants a little before the disease has appeared in the foliage, or at least at the very first appearance of it. "The usual moulding practised in all countries," writes Mr. Jensen, "is a flat moulding, by which the uppermost tubers are only covered by one or two inches of earth ;" but the Jensenian system requires, after a preceding flat moulding, a

high and sharp moulding, by which the upper surface of the uppermost tubers is covered with about 5 inches of earth. To effect this, it is necessary that the ridge be so high that the top of it is 10 inches or 12 inches above the surface of the adjoining furrow, whilst the ridge must be very broad at the bottom: this system also requires that the tops of the potatoes shall be moderately bent to one side, with a view to prevent the rain-water from running down the stems and thus carrying the spores outside, as Mr. Jensen thinks, to the tubers. By this contrivance more spores will fall between than upon the ridges. Mr. Jensen advises that the potatoes be not lifted before the diseased foliage has quite withered, because the tubers will become sprinkled with the fungus spores from the leaves and stems. "For six days," Mr. Jensen writes, "the harvested tubers will appear to be sound, but on the seventh or eighth day, according to temperature, they will suddenly show marks of the disease. It is not even sufficient that the leaves are withered before the lifting; they must have been so for three or four weeks, otherwise many spores will be found capable of germinating, and thus be dangerous to the tubers when the latter are taken out of the ground." Mr. Jensen sums up his views with the following general rules:—

1. The ground must be thoroughly worked, so that the potatoes may be planted in friable earth, which affords a better means of protection than a lumpy soil.
2. The potatoes should be planted (pretty early) at a distance between the rows of at least 28 in. or 30 in. A greater distance is not required by the system, but if closer it would impede the protective moulding.
3. The first moulding must be flat, so that the formed ridge be broad on the top and only about 4 in. high. This moulding may be repeated if it is thought advisable.

4. The protective moulding must be applied as soon as the disease-blotches make their appearance on the leaves of the haulm. If this has not occurred before wheat-harvest-time, the moulding ought to be executed then, without waiting for the appearance of the disease-blotches.
5. The protective moulding is performed by throwing up from one side of the row of plants a high ridge with a broad base, and running to as sharp a point at the top as possible. The covering of earth thereby produced over the upper surface of the uppermost tubers must be about 5 in. to begin with; later, by the settling of the earth, and by sliding down, it will, as a rule, preserve a thickness of about 4 in. Simultaneously with this moulding, the potato-tops are gently bent over towards the opposite side of the row, so as to give the top at least a half-erect position.
6. The flat and the protective moulding, where potatoes are only grown on a small scale, may be done with a hand-hoe; on a larger scale these operations ought to be performed with a moulding-plough, the "Protector," which is constructed to meet the necessities of the described system.
7. In order to prevent after-sickness, which may often be exceedingly great, the potatoes must not be lifted before about three weeks after the last leaves in the potato-field are withered.
8. If the potato-tops are cut off and carried away, which, for the sake of the quantity and quality of the crop, ought not to be done before the leaves, in the main, are withered, the lifting may, as it seems, without danger of after-sickness, take place about six days after such removal.

Where this method of culture can be conveniently practised, we think the result can be no other than beneficial. We look upon the difficult process of bending the

haulm to one side as not dissimilar in its aim and results from the common practice of removing it altogether. In both instances it reduces the yield of large tubers, and at the same time, as we think, has a tendency to prevent the mycelium of the potato fungus reaching the tubers by the inside of the haulm.

Every one who has experimented with potatoes knows that it is possible to infect tubers with the disease from the spores produced on the leaves. This infection is more readily produced in the eyes where the skin or bark of the tuber is thin and delicate. Infection, however, from the outside of the tuber inwards, is the exception and not the rule. From our own experience, we believe the disease generally reaches the tubers by travelling down the interior of the stem, and that in the majority of instances the interior of the tuber is the first part affected, and the disease then works from the inside outwards.

It commonly happens that potatoes are harvested in an apparently sound condition, but during the winter or early spring the stored tubers are destroyed by the fungus of the murrain bursting through the skin or bark from the inside to the outside. It is also a fact of common observation that when a large number of apparently sound potatoes are cut for seed, disease patches, either large or small, may be seen in the central parts of the tuber, with no apparent connection with the sound parts outside. At the beginning of January 1884 we received a letter from one of the largest potato dealers in this country, complaining of a large crop of unsalable potatoes; the tubers were apparently perfectly sound outside, but full of disease within. A selection of the tubers was also sent on for our inspection, and the sharpest searching failed to detect any disease patches outside; the interiors of the tubers, on the contrary, were full of dark-brown corroded murrain patches. In this bad case,—and we know of very many similar ones,—it seems impossible that the disease could have been derived through the bark of the tuber,

which, in every instance, was apparently perfectly intact. Another instructive case is given in the *Gardeners' Chronicle* for 1st March 1884, p. 283.

Mr. Jensen states that it may be said with full certainty that the disease either never reaches the tuber by growing through the stems, or, if it does so happen in a few single plants, which he says, to his knowledge, has never been proved, it is of so rare an occurrence as to be of no practical consequence.

A series of test experiments has been instituted this year at the garden of the Royal Horticultural Society at Chiswick, where Mr. Jensen's instructions will be rigidly adhered to. At the time of planting, when some of the tubers were cut for sets, it was observed that the disease was apparent in the interior, with no trace whatever of disease on the skin or bark. The bending over of the brittle haulm we consider a delicate operation, which is hardly suited for unskilled rustics; and if the easily-broken stems become severed instead of bent, the process becomes identical with the old plan of removing the haulm altogether. A broken haulm is synonymous with the destruction of leaves, and if the leaves are lost no starch can be formed for subsequent storage in the tubers. The mere gathering of the stems together for bending over must be injurious to the potato plant, as it prevents the leaves from receiving their requisite amount of light.

We consider the immunity from disease of earthed-up potatoes, with bent haulms, is less owing to the power possessed by the earth of filtering the fungus spores, and so preventing them from reaching the tuber, than to the effect of the earth in keeping the tubers whole and sound. Mr. Jensen has also devised what he terms a disinfecting apparatus. This has been described and illustrated by Mr. C. B. Plowright in the *Gardeners' Chronicle* for 5th April 1884. According to Mr. Jensen, a temperature of 77° F. kills both the mycelium and spores of the *Peronospora*, provided the heat be continued for a sufficient

time, and that a considerably higher temperature does not impair the germinating power of the potato. Mr. Jensen states that the exposure of tubers to a dry heat of 100° or 105° F. for four or five hours is the best mode of disinfecting them. This disinfection, it appears, should be carried out in an oven, which has to be carefully watched the whole time, and it is necessary that the heating process be continued for some hours to ensure the deeper parts of the tubers being raised to the requisite temperature. Mr. Jensen recommends for small experiments the construction of a double box capable of holding water in its interior; the space between the inner and the outer box being filled with some non-conductor of heat, as chaff. The inner box is filled with water at a temperature of 100°-120° F. Into this are placed tin or zinc cylinders, about five inches in diameter, containing the tubers to be disinfected, and in these cylinders the tubers are allowed to remain. By the employment of narrow cylinders like the above, the potatoes are more readily heated than is the case if wider ones are used. A thermometer in the water is essential to ascertain its temperature. It may require an addition of warm water once or twice, according to the heat of the surrounding atmosphere, and the efficacy of the non-conducting medium employed. In a later communication Mr. Plowright states that the tubers must, for not less than four hours, have a temperature not below 104° F., and if this rises to 115° F., no harm will be done to them, and that it is not safe to go beyond 130° F.

The apparatus has, of course, been founded on the idea that many potatoes apparently sound at the time of planting, yet contain living hibernating fungus mycelium, and that this mycelium grows with the young potato plant, and such diseased plants act as centres from which the potato fungus spreads. Our observation and experience of growing potatoes does not lead us to look upon this as always the case; and we must leave it for practical men

to decide whether repeated earthing-up, skilful haulm-bending, and disinfecting with a hot-water apparatus and assistants watching a thermometer, can be made a commercial success.

Disinfection, even if effectual, merely secures a possible healthy start of the young potato plant,—it by no means secures the potato from the attacks of spores in June or July ; these spores may come from neighbours' fields, where the potatoes have not been disinfected, or from tomatoes or other plants, and so all the labour of disinfection may be lost. It is obvious that, unless all the seed-potatoes in Britain are disinfected, little or no good can accrue from the use of a few sets of apparatus. Mr. Jensen thinks this part of the subject "cannot be considered an unworthy object for legislation" (*Gardeners' Chronicle*, p. 616, 10th May 1884), which we suppose means that farmers should be compelled by law to use a hot-water disinfecting apparatus before planting potatoes.

Mr. Jensen appears to believe, judging from Mr Plowright's communications, that the planting of diseased sets causes an early appearance of the disease, and that disinfection has a tendency to make the disease late. He seems to conclude from this that constant disinfection would at last make the fungus so late in its appearance that the potatoes would be mature before the fungus could grow. We are inclined to think, however, that the fungus would change its nature so as to agree with the new habit of the potato. Parasites always modify their habits to suit any change of nature in their host.

We have shown that Mr. Jensen's views were more or less anticipated by Dr. Jeffrey Lang more than a quarter of a century ago, and the earthing-up system has been advocated both here and in America. We are inclined to think that practical agriculturists would never have dropped this treatment if it had contained the elements of commercial success.

Mr. Jensen's views will be found reported at length,

with various comments from correspondents, in the volumes of the *Gardeners' Chronicle* for 1883 and 1884. Personally, we are sorry to say that we esteem many of the statements put forward by Mr. Jensen as contrary to fact. We say this without disrespect to Messrs. Jensen and Plowright, who have certainly made a vigorous attempt to ward off the attacks of the potato disease ; and for this they deserve the hearty thanks of all practical men. Their communications are, however, too voluminous and involved for any complete reply here. Practical potato growers, if so inclined, must sift, weigh, and compare the numerous statements brought forward for themselves.

We highly esteem Mr. Baker's suggestion regarding the potato termed "Darwin's Potato," *Solanum Maglia*, Sch., and *S. Commersoni*, Dun. The evidence brought forward by Mr. Baker seems to indicate that *S. Maglia*, Sch., would well suit our humid climate ; and *S. Commersoni*, Dun., appears to naturally resist the *Peronospora.*

In 1874 and 1875 a report was widely spread in this country through one of the scientific societies that Professor De Bary of Strasbourg had discovered an alternation of generations in the life cycle of the *Peronospora* of the potato murrain,—that he had found that the fungus passed one part of its existence on clover, just like the rusts and mildews of corn are assumed by some to live on barberry bushes and borage. The scare had no effect on the men of science in this country ; the statement was received in silence, like the statements regarding the Colorado beetle. In America, however, the case was different, for when the report of the assumed discovery reached that country it was believed, and notices appeared in the agricultural reports published at Washington, and in several agricultural journals in different parts of the country, warning farmers—according to Professor W. G. Farlow in the *Bulletin of the Bussy Institution*, part iv.—that in consequence of Professor De Bary's discoveries no potatoes should be planted after clover and other fodder

crops. Professor Farlow has stated, and no doubt correctly, that Professor De Bary never made the statements attributed to him by a few of his friends in this country.

It ought not to be difficult on well-conducted farms to keep the fields clear from rotting potato refuse. The working men and boys should be taught, as a rule of the first importance, that all potato refuse should be scrupulously gathered together and either burnt or deeply buried. Stones are always gathered together on farms by boys and girls. When vegetable refuse is incorporated with dung, this material by its warmth and moisture keeps the germs of nearly every known plant disease alive and in good condition through the winter for a renewed burst of vitality in the spring or early summer. It has been said that when potatoes are grown near chemical works they are frequently free from disease, as sulphurous acid gas or some other gaseous impurity proves fatal to the fungus of the murrain.

CHAPTER XXXVII.

PARASITIC FUNGI AS FOUND IN A FOSSIL STATE.

It is a curious fact that representatives of some of our common parasitic fungi are found in a silicified state in fossil plant stems and roots of great antiquity. Some of these parasites were in existence in company with the higher cryptogams in Palæozoic times. Indeed it is probable that some fungi, not dissimilar in structure from fungi which are now parasitic, led in remote geological times a non-parasitic life upon the ground. We still have a *Botrytis* named *B. terrestris*, Pers., which is frequent on the naked ground. The species belonging to *Botrytis* are very similar with the species described under *Peronospora*, and they were till quite recently all grouped together.

The late Mr. Charles Darwin informed us that more than forty years ago, Mr. Robert Brown, then Keeper of the Department of Botany at the British Museum, showed him silicified fungus mycelium in slices of fossil wood.

Mr. William Carruthers, F.R.S., the present Keeper of Botany at the British Museum, South Kensington, has described silicified fungus mycelium resembling that of a *Peronospora* found in the tissues of a fossil fern named *Osmundites Dowkeri*, Carr., from the lower Eocene strata of Herne Bay. The same gentleman has also detected a fungus in a fossil *Lepidodendron* from the coal measures; and Mr. Butterworth, of Oldham, has also met with a fungus in the vascular axis of *Lepidodendron*. A portion of the latter example was drawn by us, and the drawings are now in the Museum of Practical Geology in Jermyn

Street London. Engravings from the same transparent slice were published by us, with a description, in the *Gardeners' Chronicle* for 20th October 1877. Mr. Carruthers also published an extremely small engraving and a brief description of the fungus in his printed address, read before the Geologists' Association in 1876. We have named this parasite *Peronosporites antiquarius*, W.Sm. To us the mycelium appears to be distinctly septate, and the large globular oogonia or zoosporangia appear to show clear traces of zoospores within their walls.

Mr. J. T. Young, F.G.S., the owner of the transparent slice of fossil *Lepidodendron*, has recently replaced the example in our hands for a new illustration; and our engraving at Fig. 139, enlarged 400 diameters, has been made direct from the microscope.

Notwithstanding criticisms to a contrary effect, we have no hesitation in repeating, after a renewed and prolonged examination of the preparation, that traces of zoospores are distinctly visible in many of the oogonia; there is no reason why they should not exist, but good reason why they should; the mycelium is septate; and the oogonia, as in all *Peronosporeæ* and *Saprolegnieæ*, are cut off from the supporting threads by distinct septa. The slice of *Lepidodendron* from which our illustration is taken has a large number of free oogonia in different parts of the silicified tissue; such free oogonia or zoosporangia are very commonly seen in *Peronospora*, as in *P. ganglioniformis*, B. The zoospores in some of these free isolated examples are much more distinct than in the characteristic group, engraved to show the oogonia only, in Fig. 139. The traces of zoospores, seen in *Peronosporites*, exactly agree in size with the zoospores of *Peronospora infestans*, Mont., Figs. 128 and 136. The genus *Peronospora* is in close and obvious relationship to the *Saprolegnieæ*, one member of which, *Saprolegnia ferax*, Kutz., is the cause of the salmon disease. Professor de Bary has even said that facts do not exclude the possibility of the fungus of the

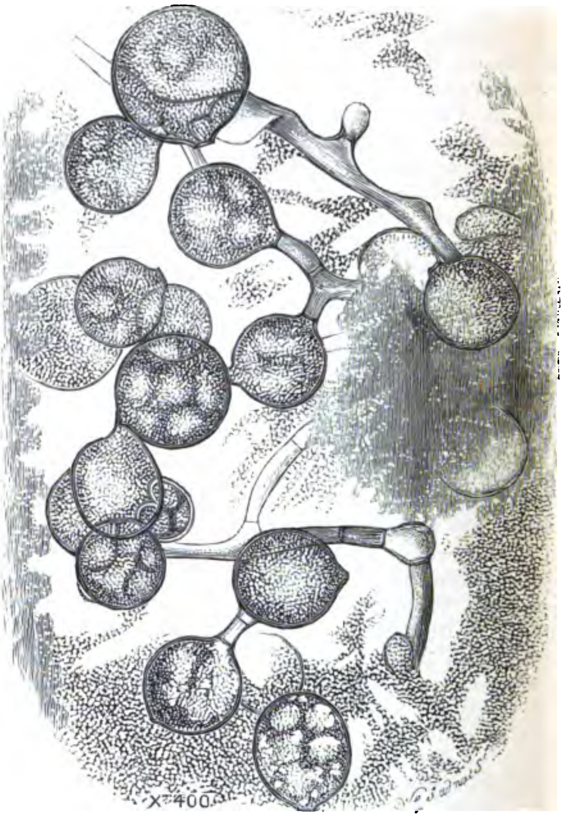


FIG. 139.—FOSSIL PARASITIC FUNGUS.
Peronosporites antiquarius, W.Sm., in a slice of fossil *Lepidodendron* from the Coal Measures. Enlarged 400 diameters.

potato disease being one of the *Saprolegnieæ* (*Journal of the Royal Agricultural Society*, p. 249, 1876). It is some-

times (as when the plants are not fully developed) impossible to distinguish between one genus and the other. *Peronosporites*, therefore, has without doubt relations with the *Saprolegnieæ*, as correctly pointed out by Professor W.

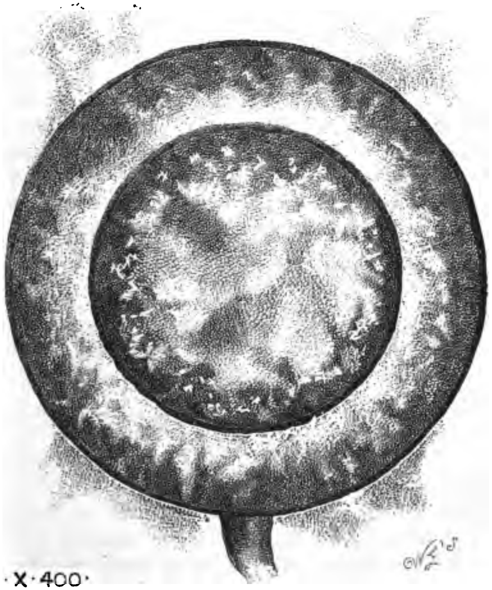


FIG. 140.—SPORANGIUM OF A FOSSIL FUNGUS.
Protomycites protogenes, W.Sm., in a slice from a rootlet of a fossil *Lepidodendron*. Enlarged 400 diameters.

C. Williamson, F.R.S., in the *Philosophical Transactions of the Royal Society*, 1881.

We have a second representative of fungi of enormous antiquity in a transparent silicified slice of a rootlet of *Lepidodendron* from the coal measures, now in the British

Museum at South Kensington. This slice exhibits numerous unusually large sporangia of a fungus not to be distinguished from *Protomyces*. Very little mycelium can be detected; and many of the sporangia of the fungus are situated in positions where the tissues of the host plant have apparently, but perhaps not really, decayed. We have illustrated one sporangium of this fungus, which may be named *Protomycites protogenes*, W.Sm., at Fig. 140, enlarged 400 diameters (*protogenes*, first produced or primæval). In most of the silicified examples an outer or exospore, and inner or endospore are distinctly visible.

This fungus presents some analogy with the alga named *Chlorochytrium Lemnæ*, Cohn., which grows within the fronds of duckweed, the spores from the zoosporangium

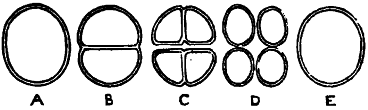


FIG. 141.
Diagram showing development of simple fungi by cell-division.

of which conjugate or fuse in the style of the zoospores (or zygozoospores) of *Protomyces*, and so produce zygospores. The observer should, however, be ready to distinguish between mere fusing, which is very common in fungi, and true conjugation, which is by no means common.

Although these two fungi have been detected in Palæozoic rocks, it must not be concluded that they are the simplest known forms of primal fungi. In *Peronospora* and *Protomyces* alike, sexual organs occur; and the fact of a separation of sexes shows a great advance upon a primordial form. Besides, the members belonging to the two genera are parasites, and doubtlessly lived in Palæozoic times, as their representatives do now, upon the living tissues of more highly-organised plants.

But there must have been a long antecedent time, when the lowest fungi were non-parasitic, and grew upon the moist warm ground as *Botrytis terrestris*, Pers., sometimes does now. In those far-off times the primordial plant was probably a mere microscopic cell or thin sac resting on the moist surface of the earth, as illustrated at A, Fig. 141. It probably increased by division, as at B, and redivision, as at C; each of the four parts soon becoming distinct, as at D, and each segment speedily reaching the original size and form, as at E. Or it might have increased by budding, like yeast. From this simple beginning many observers believe it probable that all plants have been developed. The primal cell might have been a fungus, an alga, or a form occupying an intermediate position between fungi and algæ, as both fungi and algæ may have originated from a primal and at present unknown stock

CHAPTER XXXVIII.

CONCLUSION.

We have now rapidly passed in review some of the most familiar forms of disease as seen in our field and garden crops, and not a few of our readers may possibly think the details as described both complicated and difficult. Yet on careful study it will be found that the courses of all diseases more or less follow one or two simple general plans. The details may vary and the colours may be changed, but the chief outlines are not essentially different from each other.

It is only in the knowledge obtained after completely mastering the life history of each disease that any preventive remedy against disease can be hoped for. With a full knowledge of the character and habit of an enemy, it can be fought under favourable circumstances, as in a bright light. Without the proper knowledge it is like fighting against a powerful, unknown, and merciless foe in the dark.

One point that must impress every reader is the extreme, almost inconceivable, smallness and attenuation of the parts of some of the most destructive of our field and garden fungi. To give an idea of this smallness, we have in Fig. 142 engraved the foot of a common house-fly, with its hairs and claws, enlarged 100 diameters. At AA are seen six of the spores or conidia of the potato fungus, *Peronospora infestans*, Mont. Each of these spores contains within itself, on an average, eight other little spores or zoospores, illustrated as free from the investing spore or conidium at B, and each of these smaller spores

has two inconceivably fine cilia or vibrating hairs, by which it can propel and guide itself over any moist surface. The large spores of the putrefactive fungus of lettuces, *Peronospora Schleideniana*, Ung., are shown at C; others of the putrefactive fungus of clover *P. exigua*,

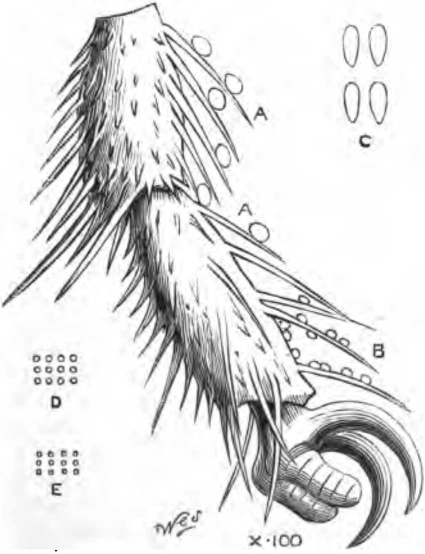


FIG. 142.
Foot of house-fly, with the spores of various parasitic fungi. Enlarged 100 diameters.

W.Sm., at D; and the spores of the smut fungus of grain, *Ustilago carbo*, Tul., at E.

Every one who has walked amongst potato plants must have noticed the small green fly or plant-louse, *Rhopalosiphum dianthi*, Schrank, shown, the natural size, at B, Fig. 143. Some of the female lice possess wings, as shown,

but so small and gauzy that they may be readily overlooked. One of these small and inconceivably thin wings is shown enlarged to 20 diameters at Fig. 143,

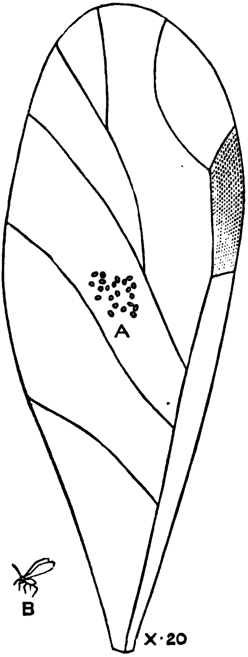


FIG. 143.
Green fly, from potato plant, natural size, and wing with spores or conidia of the potato fungus, *Peronospora infestans*, Mont., at A. Enlarged 20 diameters.

and on the wing at A, engraved to the same scale, are a number of conidia or spores of the potato fungus. Small as these germs are as seen on the greatly enlarged wing,

yet each atom under favourable circumstances encloses no less than eight other atoms, each furnished with two vibrating hairs, and endowed with the power of sailing rapidly about in any non-corrosive film of moisture.

It need hardly be said that various insects and flies, both large and small, commonly eat or imbibe fungus spores. The spores are not only to be seen dusted over the wings or sticking amongst the hairs of the legs, but they are quite as commonly seen inside the insects as out; this is especially well seen in such small transparent insects as plant-lice or aphides. The spores are carried about with the juices inside the bodies of the insects, and may not only be found in the body, but inside the limbs, and even within the almost invisible antennæ or horns. The spores of various fungi not only stick to the bodies of insects, but they germinate upon them and produce mycelium outside, and sometimes, inside their bodies. Mr. G. B. Buckton, F.R.S., in commenting upon our observations on this subject in his *Monograph of British Aphides*, says the facts need cause no surprise.

Small as some of these organisms or parts of organisms may be, it must not be assumed that we are acquainted with the smallest objects of nature. On the contrary, every new and true observation about minute things indicates that what we already know regarding small things is as nothing when compared with what is not known, and what at present we seem to have but little prospect of knowing. The most perfect and powerful telescopes cannot resolve the more distant nebulæ into stars, neither can the most perfect microscopes display to our sight numerous atoms which are believed to exist, but which cannot be seen. Persons possessed of strong vision can often see, both with the telescope and microscope, objects that are invisible to persons of ordinary sight. It would be very rash, therefore, for any observer to say that certain objects or characters do not exist simply because that observer cannot see them. Neither

is it always wise to say too positively that doubtful characteristics are certainly present; it is safer under critical circumstances to say the characters appear to be present or non-present.

The cilia or vibrating hairs of the zoospores of the potato fungus are so excessively attenuated that, when the highest magnifying powers are used, and with the cilia close to the object-glass, it commonly happens that both hairs cannot be seen at the same time: an alteration of the focus, small beyond description, is necessary to see first one, then the other. When a zoospore becomes quiescent and germinates, the cilia vanish. They either dissolve or break up into the finest dust—dust so small that no figures can express the minuteness of the particles. Now it is well known that all parts of the potato fungus are so potent with life that every visible atom will grow and reproduce the fungus. It is quite possible, then, that, just as every atom of a mycelial thread of this fungus will continue its growth to the perfect form, so every atom of a broken up flagellum—perfectly invisible to the eyes even when the highest powers of the microscope are used—may be capable of carrying the poison and at length reproducing the perfect form of the fungus in the potato plant.

We think it would be well if all agriculturists would set apart a small portion of each farm or garden for experimental purposes, each farmer taking a personal, practical, and scientific interest in his own special crops.

Seeds of all sorts should be selected from the healthiest parents. Indiscriminate seed planting should never be practised. By constantly selecting seed from plants free from disease, hereditary disease might at length exhaust itself and be extinguished. We think it impossible to over-estimate the importance of the fact of the hereditary nature of disease in plants and animals. Mr. Charles Darwin, writing in his *Animals and Plants under Domestication*, vol. ii. p. 7, says: "Unfortunately it matters

not, as far as inheritance is concerned, how injurious a quality or structure may be if compatible with life. No one can read the many treatises on hereditary disease and doubt this. . . . A long catalogue could be given of all sorts of inherited malformations, and of predisposition to various diseases." Under "Cataract of the Eye" Mr. Darwin writes at p. 9: "When cataract affects several members of a family in the same generation, it is often seen to commence at about the same age in each—*e.g.*, in one family several infants or young persons may suffer from it, in another several persons of middle age." This latter observation has a direct bearing on the hereditary diseases of plants which notoriously appear at certain stages of the plant's growth. Under "The Horse" Mr. Darwin quotes Youatt on p. 9, who writes: "There is scarcely a malady to which the horse is subject which is not hereditary." At p. 11: "Andrew Knight, from his own experience, asserts that disease is hereditary in plants, and this assertion is confirmed by Lindley." And again: "Seeing how hereditary evil qualities are, it is fortunate that good health, vigour, and longevity are equally inherited. . . . As to the inheritance of vigour and endurance the English racehorse offers an excellent instance. Eclipse begot 334 and King Herod 497 winners."

Facts like the above should serve as key-notes, and strongly impress all practical agriculturists. Every diseased plant or seed should be mercilessly struck out and destroyed. No owner of herds and flocks would allow badly diseased animals to breed, and, in the same way, no agriculturist should take his seed from plants notoriously infected. By a constant selection of seeds from plants—the freest from disease—at length races might be obtained almost entirely free from disease. If it should some day be proved that disease does not exist in seeds, it will not be denied that certain plants inherit a strong tendency to become diseased.

Sometimes, after several healthy generations of plants, the progeny may revert back to disease in an analogous way with the many similar instances so well known amongst men and other animals. The disease in these cases is sometimes derived from some remote and perhaps forgotten ancestor.

A rotation of crops is of high importance as regards disease, for a fungus that destroys turnips or cabbages will probably not injure corn, and neither will injure clover. As a rule any given destructive fungus keeps to one Natural Order of plants, often to one genus, sometimes to one species. Any fungus capable of invading plants belonging to several Natural Orders is an exception to the rule.

In writing these concluding words we are strongly impressed by the fact of how little has really been described. The mere margin of each subject has been barely approached, and the anatomy and physiology belonging to each disease only glanced at. The subjects discussed have only been presented in bare outline, and many of great importance have not been mentioned at all—as the diseases of beans, beet, cucumbers, mint, hops, etc. A large subject awaits description and illustration in the nature of canker and the diseases of our fruit crops, our grapes, peaches, nectarines, apples, pears, gooseberries, strawberries, figs, melons, etc. Another of equal importance presents itself in the diseases of our timber trees, our firs, pines, larches, oaks, elms, and latterly, yews.

In closing, we advise all students of nature to think as well as observe, for a man may be a good observer and not a good thinker, and a good thinker may be but a poor observer. Some observers, by always applying themselves to the elucidation of minute things, have apparently made themselves mentally incapable of broad generalisation and the understanding of great ones.

The greatest possible caution is necessary in making deductions from observed facts. So long as an observer

keeps to a record of facts, he is doing useful work, and work that cannot be questioned; but as soon as theories, hypotheses, and deductions are introduced, an element of uncertainty creeps in. The mere superficial appearances presented by Nature are seldom to be depended upon. They are often deceptive, and exhibit a tendency to lead an observer in the wrong direction. We may refer as examples to the structure of the blue mould fungi of our provisions, named *Eurotium repens* and *E.* (*Aspergillus*) *glaucus*, Lk. In these fungi sexual organs have been described and illustrated by Professor De Bary, but rejected as such by M. Ph. Van Tieghem (*Bulletin de la Société Botanique de France*, p. 96, 1877); to the supposed sexual condition described and illustrated by Tulasne and De Bary under *Erysiphe* and *Peziza;* both the latter observations greatly need confirmation; and to the cases of erroneous interpretation mentioned elsewhere in this volume. With a full knowledge of the deceptive superficial appearances frequently presented by natural objects, Mr. Charles Darwin once said that Nature "will tell you a direct lie if she can" (*Trans. Essex Field Club*, vol. iii. p. 67).

It is not wise to become an unqualified believer or disbeliever in any hypothetical views. Our knowledge of Nature is at the best extremely imperfect, and the very little we know of her and her ways is as nothing when compared with what we do not know.

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